EMERGENT LEARNING: THREE LEARNING COMMUNITIES AS COMPLEX ADAPTIVE SYSTEMS.

Dissertation
by
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submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

May, 2009
EMERGENT LEARNING: THREE LEARNING COMMUNITIES AS COMPLEX ADAPTIVE SYSTEMS

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In the 2007-2008 school year, the author conducted a collaborative case study (Stake, 2000) with the goal of discovering and describing “emergent learning” in three high school classrooms. Emergent learning, defined as the acquisition of new knowledge by an entire group when no individual member of the group possessed it before, is implied by the work of many theorists working on an educational analog of a natural phenomenon called a complex adaptive system.

Complex adaptive systems are well networked collectives of agents that are non-linear, bounded and synergistic. The author theorized that classes that maximized the features of complex adaptive systems could produce emergent learning (a form of synergy), and that there was a continuum of this complexity, producing a related continuum of emergence. After observing a co-curricular jazz group, an English class, and a geometry class for most of one academic year, collecting artifacts and interviewing three students and a teacher from each class, the author determined that there was indeed a continuum of complexity.

He found that the actively complex nature of the Jazz Rock Ensemble produced an environment where emergence was the norm, with the ensemble producing works of music, new to the world, with each performance. The English section harnessed the
chaotic tendencies of students to optimize cognitive dissonance and frequently produce emergent learning, while the mathematics section approached the learning process in a way that was too rigidly linear to allow detectable emergence to occur.
Acknowledgements

My most heartfelt thanks go to my wife Kerry. She supported the decision to pursue a doctorate and then, when she learned that she would endure neurosurgery and surgical procedures to remove two kinds of cancer, she insisted that I continue, often causing me to leave her side during her difficult recoveries. To her, my hero, I dedicate this work and the rest of my life.

This work would also not have been possible without the academic support of a legion of students and faculty at the Lynch School of Education at Boston College. At the head of that pack is Dr. Pat McQuillan, whose enthusiasm about complexity theory, willingness to work year-round, and patience while guiding a full-time teacher through the dissertation process were seemingly infinite.

Thanks to the entire cohort who entered the Curriculum and Instruction program in the fall of 2004. In particular, to Dianna Terrell, whose generosity with her excellent notes allowed time away from class to be by my wife’s side, and to Margarita Zisselsberger, Aubrey Scheopner and Karen Shakman for reading early drafts and providing so much good advice during the proposal process. Thanks also to Dr. Leigh Patel Stevens and Dr. Curt Dudley Marling for serving on my committee, providing a truly constructive diversity of perspectives and advice.

Finally, thanks to all of the participants in this study. Their generosity of time and their thoughtfulness were boundless and I hope that by telling their stories, this work will cast light on their brilliance, dedication and kindness.
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Emergent Learning: Three Learning Communities as Complex Adaptive Systems.

CHAPTER ONE – THE THEORY OF COMPLEX ADAPTIVE SYSTEMS

There is great variety in what are called “schools.” Different curricula are taught by different people under different circumstances, but somehow one can recognize all of these situations as schooling. Students are assembled in classrooms of all kinds across the world, from lightless huts in the rainforest to the most fully equipped, modern first world high schools. Perhaps the only true commonality that ties together the concept of “school” is the idea that students are grouped together in one way or another, often in what is called a “class” or “learning community.” If they were not, the process would be called “tutoring.”

Despite the seemingly obvious statement that students in schools are grouped, surprisingly little attention is paid to the role of the group in the learning process. Mainstream research, policy and practice all show evidence that they virtually ignore the role of the group and focus almost exclusively on individual learning. Constructivists speak of how individuals each construct their own universes given the stimuli around them. There is little talk of how groups affect those constructions other than as peripheral influences, and traditional constructivists rarely consider that the entire group may generate a common construction – that the group itself may be a single learner. The policies outlined in No Child Left Behind legislation give great emphasis to individual accountability. Individuals are tested to be sure that they all have the same core of knowledge as if each had been tutored at home, and the state was checking to see if all of
the households in the area were teaching the same thing. Once these individual tests are given, however, they are sorted by group and averaged. The average is then presumed to say something important about that group (for example, if a certain subset of a school’s population is learning at an acceptable rate). This group analysis is conducted without ever doing any other kind of assessment of the group as a whole, while it is functioning. When managing classrooms, teachers are often evaluated on how well they prevent group members from interacting with each other, with a positive learning environment being defined as one in which all eyes are on the teacher. All of these examples give evidence that many mainstream researchers, policy makers, and practitioners imagine that teachers simply tutor thirty students at once rather than recognizing that group learning dynamics are a defining characteristic of schooling. In classrooms, as in other organizations, individuals can become sufficiently interdependent that they participate in a reflexive process of creating and being created by the group to such an extent that there can be true group learning (Stacey, 2003).

This study sought to investigate the learning of three entire groups of students, considering that each group was a single entity – a learning unit. It challenged the notion that the classroom was in all cases a simple collection of constructors, and examined the possibility that group processes could act as a source of learning for the entire group. The primary goal of this study was to determine whether new information, never before possessed by the students or even the teacher, could enter a group by a specific type of networking called a “complex adaptive system” (CAS). In CAS theories, synergistic
results are often called “emergence.” The primary goal of this study has been to discover and describe “emergent learning.”

Toward that end, this work describes a collaborative case study (Stake, 2000) of three learning communities from Metropolitan Catholic High School\(^1\) conducted primarily during the 2007-2008 school year. Each class was observed at least eight times between November and May, and four members of each class were interviewed (three students and one teacher). Assessments, student work, school documents and other archival material were all collected. The three groups were: a jazz group, known as the Jazz Rock Ensemble, for which students auditioned; a freshman English class; and a geometry class for sophomores. All of these learning communities were observed in an attempt to identify whether the characteristics of complex adaptive systems could be observed, to what extent emergent learning occurred and whether or not there was an overall continuum of complexity.

In order to fully understand this research, one must first be familiar with the idea the study was designed to test – the theory of complex adaptive systems. Regrettably, since this is a relatively new field, there is not yet a universally accepted vision of what precisely constitutes a complex adaptive system. Fortunately, however, some common themes have emerged from the theoretical literature.

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\(^1\) Pseudonyms are used for all participants and places in this study.
Introduction to Complexity Theory

In general, complexity theory seeks to answer the questions that have frustrated practitioners of more traditional outlooks across a broad range of disciplines (Davis & Simmt, 2006). How can ants, each one remarkably simple, form a community that can do such complex things as build structures out of their own bodies or respond in a unified way to the presence of danger or of food (Johnson, 2001)? Why does a small action on the global atmosphere sometimes begin a chain of events that results in dramatic weather changes half way around the world, while the same action sometimes results in no change at all (Capra, 1996)? And why is the study of learning so confounding that David Berliner (2002) has called it “the hardest science of all?”

Complexity theory asserts that what is happening in each of these cases is the individual agents, be they ants, water molecules or people, have become intertwined in a nonlinear network, forming “complex adaptive systems,” and that the characteristics of these systems then transcend the sum of the properties of the individuals of which they are made; they are synergistic. The reason we have found these situations so difficult to investigate is that researchers have developed a habit of using the technique of “analysis by dissection” to investigate far too many different kinds of phenomena. We pick apart the component parts of machines, organisms, ecological systems and any number of other entities and assume examining these parts will reveal the nature of the whole. This dissection method, however, is not useful when the component parts have no information to give about the emergent properties of the whole system. Looking at an individual water molecule tells one nothing about the weather system of which it is a part, just as
examining a single ant or human reveals little about what is happening in an anthill or classroom. As prolific complexity researchers Brent Davis and Dennis Sumara (2006) put it, complex adaptive systems must be studied “at the level of their emergence.”

To do so, however, one must first be able to identify complex adaptive systems in the first place. This is where the relative youth of this field within educational circles presents some challenges. Complexity theory is, not surprisingly, so complex that many theorists (Notably Auyang, 1998; Capra, 1996; Davis & Simmt, 2006; Johnson, 2001; Ollhoff & Walcheski, 2002; Senge, 2000; Wheatley, 1992) have chosen to devote entire books to a definition. Some, however, have attempted to consolidate the properties of complex adaptive systems into lists. It seems every theorist has his or her own list of characteristics, qualifying properties, or optimal conditions for complex adaptive systems, each slightly different from the next. This chapter represents an attempt to synthesize these lists into a relatively concise definition which will then be used as a touchstone for empirical observations (See Appendix A for a summary of these lists).

Complex adaptive systems are well-networked collectives of discrete agents that are: nonlinear, bounded and synergistic. They are well networked collectives in the sense that each individual retains its discrete identity and power to act of its own accord, while it is at the same time engaged in some kind of a relationship with its neighbors. These systems are nonlinear in that they do not react to stimuli in a way that is predictable according to simple “if . . . then” statements. For example, in a non-complex system, one may be able to say “If I add fuel to a car, then it will travel farther.” In contrast, if I give that same fuel to a complex entity like a person, then she may drive farther, or use it to
mow the lawn, sell it, give it away, or any number of other things that are difficult to predict exactly.

Complex adaptive systems are *bounded* in that their unpredictability has limits. A person given a can of gasoline is very unlikely, for example, to successfully use it to put out a fire or nourish a child. Finally, complex adaptive systems are *synergistic*. They are more than the sum of their parts. Moreover, they produce effects that are different than could be accounted for by the simple addition of the properties of the individuals. This is often called “emergence.” Among the goals of this study will be to investigate the degree to which learning is such an emergent phenomenon.

The ‘Problem’

The purpose of this study has been to determine to what extent (if any) three “ordinary” learning communities (which is to say, classes that are *not* designed by a researcher to demonstrate any specific learning theory) in a particular school will exhibit the characteristics of complex adaptive systems. Observations, interviews and artifacts were analyzed to answer a number of questions that emerged from this central problem.

1. Were these three learning communities complex adaptive systems at all, or were they mere collections of individuals? What factors came into play in making a class a complex adaptive system?

2. To what degree was each characteristic of complex adaptive systems present in each class, and to what extent did these variances result in different levels of complexity among classes?
3. Could learning in any of these learning communities be described as a synergistic emergent phenomenon as defined by complexity theorists? In other words, could the interactions of members of a group result in new knowledge – not theretofore present in any agent of the system (students or teachers) – being generated by the group, and would that knowledge then feed back upon the students to result in individual learning? If so, what would it look like?

Significance

Very little research on complexity theory has examined the classroom environment, and when it has, the researcher has almost always been the teacher, co-teacher, or facilitator. Only one of the empirical studies reviewed in chapter two examined what Americans would call high school classes, and it is from Canada (Sinclair, 2004). The only other study that looked at high school students did so mostly with respect to their course selection and overall achievement (Polite, 1994). An extensive search uncovered no articles that examine private school students, and all of the studies that examined a particular subject (either in K-12 classrooms or from the perspective of teacher education) looked exclusively at mathematics learning. This study sought to expand the research base, albeit microscopically, to include a view from a private (Roman Catholic) secondary school, an examination of subjects other than mathematics (music and English), and a look into American high school classes that were not being taught or co-taught by the researcher. Each of these is new to complexity theory research.
Perhaps more importantly, in addition to contributing to this young field for the benefit of theorists, this study seeks to provide observations and insights that are relevant to classroom teachers. If classroom learning can be understood by viewing students as agents making up a complex adaptive system rather than as vessels to be filled or individual constructors of their own reality, then the consequences regarding teachers’ and policy makers’ perceptions of what constitutes appropriate teaching and learning could be significant.

Towards a Definition of Complexity Theory

I define complex adaptive systems as *well-networked* collectives of discrete agents that are: *nonlinear*, *bounded* and *synergistic*. This section explores this definition further, examining each element in greater detail and explaining how this short statement represents a synthesis of ideas from many other complexity theorists.

It bears mentioning that the unavoidably linear medium of English language writing significantly limits any author’s ability to fully express the interwoven nature of the concepts within complexity theory. As such, a reader familiar with complexity may look at any one of the examples given below and realize that an example given for the well-networked nature of a system is also an example of how it is bounded, or that an example of synergy also shows the nonlinearity of a system. In fact, the more one makes such connections, the better one understands how complex adaptive systems work. Given this inherent resistance to categorization, the characteristics and examples below are provided as an imperfect tool for entering into an understanding of complex adaptive
systems, with the full knowledge that these categories are so mutually specifying that the lines between them quickly begin to blur.

In addition, this definition represents an attempt consolidate longer lists of the characteristics of complex adaptive systems (i.e., Pines 1998) with the hope of simultaneously creating a manageable definition, while also retaining the meaning provided by the various list items. These characteristics were obtained by examining the work of many theorists and empirical researchers in complexity theory. These authors’ definitions, descriptions, and qualifying conditions for complex adaptive systems were then compared, and a number of similarities were found. In much the same way that one might code qualitative research by a reflexive process of assigning categories, so was this body of this literature scrutinized for common themes. The four characteristics used in my definition (well-networked, nonlinear, bounded and synergistic) represented the dominant themes revealed by this examination. Though most lists of characteristics of complex adaptive systems are far longer than mine, I have found that many aspects highlighted by others can, in fact, act as descriptors of these four main points. As such, in the examination below, some of the four characteristics in this definition have been subdivided to show how various concepts from the lists of others contribute to these overarching categories.
Well-networked

There is a difference between a collection and a collective (Davis & Simmt, 2006). It is not unusual to find one’s self in a collection of people – as with a group of strangers in an elevator. All of the agents have been collected together, but there is, most of the time, little interaction among them. As such, no particular group dynamic ensues. This differs greatly from what happens in a classroom. Here, relationships are forged. Students and teachers interact with one another to solve problems or discuss literature. Because of these relationships, it is possible that this well-networked interaction will become a collaborative, which may then result in group-wide learning that is not manifest in the disconnected collection of people on the elevator. Theorists suggest that the transformation from collection to collective requires a network with a particular set of characteristics: agency, short-range relationships, and nested or fractal networking.

Agency

Collectives are not the sites of so-called group-think. There is nothing complex about collections of identical particles, or of automatons, which can do only what they are told. If every individual in the group does or thinks the same thing all of the time, stagnation occurs. In this case, there can be no change – none of the adaptivity or emergence that will be explained in future sections. Instead, part of the power of complex adaptive systems comes from the fact that each of the agents is an independent entity, able to contribute new ideas – to introduce perturbations into the system – that spur it to make some kind of change (Ollhoff & Walcheski, 2002; Zellermayer & Margolin, 2005).
One focus of this dissertation has been to investigate whether learning represents such a change.

Focusing on relationships within all kinds of human systems, Ollhoff and Walcheski (2002) take a particular interest in the importance of locating agents in the proper place on a continuum that runs from completely undifferentiated on one end (so well networked that no individual identity is present) to so completely differentiated on the other end that an agent is no longer a member of the network at all. In the middle of these two extremes exists a balanced state where “a well differentiated person can articulate their own goals but still remain connected to those with opposite goals” (p. 31). In this state, both individuality and networking can be optimized, allowing the system to efficiently generate and process new information. They explain that, in contrast, when a system is made of poorly differentiated individuals, it becomes “mediocre” out of a desire to avoid conflict. This is when group-think sets in. On the opposite end of the continuum, one can imagine a system wherein all agents are so completely entrenched in their positions and detached from each other that they would simply cease to act as a collaborative in any way. The elevator is an example of this situation. People do not interact, so no complex system forms.

Another important aspect of agency within the larger context of complexity theory is the idea that, though individual agents act, resulting changes can occur at the level of the entire system. In particular, a system may ultimately self-organize (a phenomenon more completely discussed in the “synergy” section below) as a result of the exchange of differences among independently acting agents (Mennin, 2007). Members of
a group can come together with unique sets of ideas and network those notions together to produce a group-wide idea that transcends any of the individual contributions. In the eighteenth century, Adam Smith introduced the concept of the “invisible hand.” Most often applied to the stock market, the invisible hand explains how individuals, all acting in pursuit of their own self interests, produce patterns of change in the market. The invisible hand is, in turn, described as a force that guides the market (Rothschild, 1994). This emergent, reflexive process is a kind of synergy.

The concept of agency also brings up the idea that diversity is a good thing in a way that transcends the benefits of learning to get along with one another. Diversity of independent agents, particularly (in human systems like classes) diversity of experience and opinion, is actually a powerful force in creating and maintaining viable complex adaptive systems. As a sometimes ecologist, I draw from the definition of “complexity” used in the environmental sciences as a metaphor. In terms of ecosystems, complexity is diversity (the presence of many different types of species) across multiple levels of organization, known as trophic levels. In other words, there are not just many different types of plants, but also many kinds of herbivores and many kinds of carnivores (Cunningham, Cunningham, & Saigo, 2003). In ecology, complexity actually means a kind of super-diversity. Environmental scientists know that complexity produces a system that is – to echo what Margaret Sinclair (2004) has said about complex classrooms – “evolvable, resilient . . . and novel” (p. 69).

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2 It might be interesting to remember this definition so as to compare it to the concept of a “fractal” discussed below.
This concept of more and different kinds of parts adding resiliency to a system would be foreign to the owner of a fancy car. A “complicated” system like a car becomes more likely to need servicing with each new part that is added. In contrast, a “complex” system, like an ecosystem, can become more stable with increasing diversity (or, even better, complexity). Highlighting the difference between complicated and complex, Davis and Sumara (1997) said, "Machines, however complicated, are always reducible to the sum of their respective parts, whereas complex systems – such as human beings or human communities – in contrast, are more dynamic, more unpredictable, more alive" (p. 117). A lawn, for example, seems like an appealingly simple ecosystem; the point is to make it as close to a one-species system as possible. Lawns are extraordinarily fragile, however. One parasite can rush across, hopping from blade to blade very quickly, destroying everything in sight. In contrast, should the same parasite attack some grass on a forest floor, it would quickly encounter something like a tree or a bush which it couldn’t eat, and would die off. The rest of the grass in the forest would be saved, and the system would reclaim the dead patch by growing something else there. The complex system of the forest is able to adapt, allowing it to continue to function, whereas the simple system fails.

Just as harmful parasites or diseases could rush easily across the lawn, so could harmful ideas and misconceptions rush across a group of people if they are either too much the same or not sufficiently empowered to express their differences. The presence of multiple agents with independent ideas provides the complex adaptive human system
with the resources to adapt to new situations (including ones that are not “threats” like group-think) and, thereby, to survive.

Short-Range Relationships

In a large enough system, there is a limit to the number of other agents with whom each individual can interact at any real level of intimacy. True – the science of ecology teaches that we are all inextricably connected, with fires in Brazil reducing the global ability to process carbon in the atmosphere and, thereby, contributing to climate change in the Arctic, to cite just one of a vast number of examples (Gore, 1992). The fact is, however, though I am connected to the global system, it is unlikely that I will be able to actually put on a helmet, grab a hose and put out those fires. This is the wisdom of the environmentalists’ mantra “think globally, act locally.” Agents are only able to influence the system directly via their interaction with a limited number of other nearby agents. Steven Johnson (2001) asserted that recent anthropological evidence suggested that the human mind can keep close track of only about 150 other minds. In a large system such as a school or a city, we are simply unable to maintain intimate connections with everyone.

Complexity theory assuages fears about these limitations, however, by highlighting the fact that complex adaptive systems can work by way of a cascade of local interactions, which build upon each other to produce system-wide change. Davis and Sumara (2006) highlighted this property by contrasting what they call “centralized” networks, in which each agent was connected only to a centralized leader, limiting
information flow; decentralized networks, where trying to interact intimately with too many other agents resulted in overload; and the happy medium of the decentralized, or scale-free network, in which interactions with relatively few agents produced optimal system functioning. Their illustration of these three networking types is included as figure 1 below (Davis & Sumara, 2006, p. 52).

Figure 1 Types of Network Architectures

They recommended an emphasis on what they called “short range relationships.” In this pattern, each agent had a manageable number of intimate connections to maintain, but was still connected to every other agent in the system via relatively few intermediaries. Since some of Davis and Sumara’s work, and a large body of research on complexity theory, deals with groups significantly larger than the ones in this study, scale-free networks are preferable. Many studies focus on entire schools, school systems, or communities. In these groups, scale-free networking works best. In a small group,
however, like a class or musical ensemble, distributed networks can also produce rich emergence. A good example of how these two networking types are related can be found in New England municipal history. When towns were very small, a good way to pool ideas was to hold a town meeting (a kind of distributed leadership). As towns became larger, however, they had to transition to representative government (an example of scale-free networking). The groups in this study are easily small enough to use town-meeting-like distributed networking. In a group of so few people as a classroom, distributed networking is a perfectly effective networking process. As such, it has been highlighted in this study. Examples of the mechanisms by which these short range relationships may result in system-wide change will be explored further in a section on nonlinearity below.

*Nested / Fractal Networking*

The mathematics of chaos theory is an important component of complexity thinking. One of the most widely publicized of these concepts is the non-Euclidian geometry of fractals. Among the most interesting aspect of fractals is their self-similarity. As a point of contrast, imagine taking a magnifying glass to a simple Euclidian shape such as a square. Pointing the glass at any part of the square might reveal a section of straight line, a right angle, or, perhaps, empty space – certainly nothing that looks like a square. Fractals, however, are often composed of shapes that are self-similar even when magnified. Consider Figure 2 below (from Kaminski, n.d.).
This representation of the *Koch Snowflake* demonstrates that a triangle, when subjected to the simple geometric iteration of flipping another triangle over and superimposing it, makes a shape like a Star of David. Repeating similar iterations over and over again produces the shape of a snowflake. The Koch Snowflake is roughly (both in the sense of being approximate and being, more literally rough) a triangle-based shape which is, in turn composed of triangular shapes, which could themselves be made of triangles. With enough iterations (many more than are pictured above) one can imagine a nearly infinite number of levels of scrutiny (in this case, levels of magnification), all showing collections of triangles. The entire geometric system is self-similar on multiple levels (Capra, 1996). Naturally, this is a very simple example. The fractal nature of shapes in nature, and of complex adaptive systems is much more involved. In particular, it is useful to note that *not* all fractal elements, even at the same level of organization (or
magnification, in the example above) must be the same size. In the same way, agents in a complex system do not necessarily exert effects of equal magnitude on the whole.

The fractal metaphor has been used in complexity theory to explain what Davis and Simmt (2006) called self-similar or scale-free networks. Just as fractals are shapes composed of similar shapes that, when reiterated, produce similar shapes, so are complex adaptive systems simultaneously making and made of complex adaptive systems. People are composed of organ systems, which are composed of cells, which are composed of organelles, and so on. At the same time, people make up families and friend-groupings, societies, governments, etc. Each of these entities is a complex system in its own right. “Each one of us is, all-at-once, a collective of wholes, a whole, and a part of a whole” (Sumara & Davis, 1997, p. 118). The nested character of complex adaptive systems is not limited to physical entities, however. Subjective understandings are nested within classroom collectivities, which are nested within curriculum structures, which are nested within bodies of knowledge such as mathematics (Davis & Simmt, 2006). At multiple levels of scrutiny, complex adaptive systems are observed. Self-similar fractal characteristics need not only manifest themselves in the organization of systems. For example, characteristics like “trust” may be important on multiple levels of an organization. Unfortunately, negative characteristics like “lack of interest” may repeat across various levels as well, such as when teachers no longer seem to care about students and students are disinterested in learning (Polite, 1994).

Related to the concept of magnification, another important factor of fractal shapes is that they are impossible to measure. Benoit Mandelbrot (1982) famously asked the
question “How long is the coast of Britain?” The point of this query is that the answer cannot be determined. Imagine that one approximated the length of the coastline to be that of an oval. That oval would have a certain length. If one then included the major bays and inlets, the length would increase. Factoring in smaller harbors and coves would lengthen the measurement of the coastline further still. With each successive increase in precision, down to the atomic level, the measurement of the coastline would increase until it approached infinity. Fractal shapes can be nearly infinitely complex, and therefore be impossible to measure reliably.

*Nonlinear*

Linear thinking, represented most simply by “if . . . then” statements, is very attractive. It is comforting to know that if one pokes a wooden block sitting on a table twice as hard, then it will move twice as far. This interaction is even describable by a very simple linear equation, \( F = ma \), where “\( F \)” is the force exerted by an object, “\( m \)” is its mass and “\( a \)” is its rate of acceleration. If one could not make these kinds of assumptions at least some of the time, it would be a scary world to live in. One would never know whether poking the block would move it so fast it would strike the person across the table. It is unwise, however, to take the next step and think that *everything* behaves so simply. With increasing complexity comes increasing (though not limitless) unpredictability. Contrast the block with poking a dog (Davis & Sumara, 2006). The number of possible reactions is now far greater – she may stay put, run away, turn and bite, bark, or exhibit any number of other behaviors – and it is much more difficult to
predict which of these she will choose. It is important to note that the complex adaptive system known as ‘the dog’ is not just acted upon, like the block, but is an independent actor as well, making linear thinking ineffective. Presumably, learning communities like classes are sufficiently complex that their responses should be similarly unpredictable. A teacher, for example, may teach in a way that has worked before, but the new system (the class) may react differently, and not learn as well as previous classes. In addition to befuddling “if . . . then” logic, characteristics of non-linearity include: operating far from equilibrium, the use of feedback loops, and the possibility of producing a “butterfly effect.”

_Systems Far from Equilibrium_

One way to describe the difference between the dog and the block is that the dog exists in a state far from thermodynamic equilibrium. Equilibrium is a state of inherent stability in which there is little net change. On the opposite end of the continuum is total disorder, where there is no organization at all. Systems like machines, or like the block, are closed. They do not interact much with anything outside the system. Ultimately, they will find themselves in a state of equilibrium, like the block sitting on the table doing nothing, and interacting very little with the environment. Open systems, in contrast, are constantly interacting with the environment (Bloch, 2004). The dog is breathing, eating, giving off waste, moving, etc. If the dog was to stop eating and breathing, it would become a closed system, and revert to an equilibrium state called “death.”
Complex adaptive systems like living things position themselves far from the equilibrium state that is the destiny of closed systems, but not quite in the completely disorganized state known as disorder. They exist in a state sometimes called “far from equilibrium” (Capra, 1996), or, more poetically “at the edge of chaos” (Lewin, 1992). In this state, complex adaptive systems are organized enough to act as a system, but flexible enough to change.

*Feedback*

Another factor that makes complex adaptive systems behave in nonlinear ways is the presence of feedback loops. With feedback loops, constant, reflexive interactions among elements of a system serve to magnify some effects and suppress others. One important feedback system is in play when one walks across the room. There is a constant interaction between brain, inner ear and limbs that keeps the walking person upright. Should one start to lose balance, the inner ear would send a message to the brain which would send a message that changed the motion of the legs, which would result in a change of position, which would be registered by the inner ear, and sent to the brain, and so on. Environmentalist Amory Lovins provided an excellent example of how such swirling interactions in an even more complex system resulted in certain kinds of phenomena. The people of Indonesia were plagued with malaria. They reasoned that if they killed all of the mosquitoes, the malaria would go away and they would all be healthy – one cause, one effect. Instead, many feedback loops ensued. The humans’ response to the stimulus of too many mosquitoes was to lay down pesticide. This fed
back into the environment and killed many wasps, which were then not present to prey on insects living in people’s thatched roofs. This fed back to the humans when the bugs ate the roofs to the point where they fell down. At the same time, the pesticide was making the cats sick. The cats then could not prey on the rats, whose fleas brought on an outbreak of the bubonic plague (cited in Gore, 1992). In this situation, a complex set of cause and effect loops produced an unexpected and, in this case, tragic emergence, when a simple, linear “if we lay down pesticide, then the mosquitoes will die” model of cause and effect was expected.

_The Butterfly Effect_

When such small inputs are made into a system of feedback loops, ultimately resulting in much more significant unexpected phenomena, it is often referred to as “the butterfly effect.” The name refers to MIT meteorologist/mathematician Edward Lorenz’s question “Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas?” (quoted in Stanley, 2005, p. 138). The idea is that a small action in a system so well connected as the global atmosphere could enter into feedback loops that would magnify its effect over time to such an extent that it could participate in determining whether or not a tornado would form.

An example from my own educational journey is more positive. Some time years ago, Cloé Chunn, one of my professors at the Audubon Expedition Institute at Lesley University ran across a book – Fritjov Capra’s _The Web of Life_. She advocated a bit for its inclusion in my master’s degree program which resulted in my reading it and having
the opportunity to find it genuinely eye-opening. I then had the chance to discuss it with my classmates, one of whom found it similarly fascinating, while the others found it dense and unpleasant. The contents of this book resided in the back of my mind until it fed back upon me when another professor, Patrick McQuillan at Boston College, as an aside, mentioned some of his work on complexity theory in a research methods class. This led me to study with him, and then to continue my work on complexity until it became the focus of this dissertation proposal. Whatever small event caused Cloe to choose to read that one book – perhaps something as small as running across it in a bookstore at a time when she had not even planned to be there – has fed back and contributed significantly to my choice of academic career. A very small event in her life has led to a dramatic change in mine.

Bounded

Though complex adaptive systems can show somewhat unpredictable, seemingly random, nonlinear behavior, they do have limits. These systems are bounded in what are most commonly called “strange attractors” (Gilstrap, 2005; Harkema, 2003; Livneh, 2005; Ollhoff & Walcheski, 2002; Wheatley, 1992). Though there is no universally accepted definition of a strange attractor (or even a common name – they are also called chaotic attractors and fractal attractors), the basic idea of a strange attractor is that it is a bounded space within which chaotic activity occurs, but within which discernable patterns emerge. These patterns have the additional features of having fractal properties and disproportionate sensitivity to initial conditions, similar to what happens in the
butterfly effect (Williams, 1997). A classic explanation is found in the story of the evolution of physicists’ concept of the structure of the atom. Niels Bohr developed a popular model of the atom that suggested that electrons move around the nucleus in orbits not unlike those of the planets around the sun. Though this remains a useful model, future discoveries revealed that his thinking was slightly too linear. Werner von Heisenberg established that one can’t predict both the position and direction of such particles at the same time. The electrons don’t move around in predictable orbits – they move around however they “like.” The solution to this unpredictability is the atomic orbital – a region of probability in which one is likely to encounter an electron. It is analogous to pointing a hose straight into the air. One can not predict the exact path of every water droplet, but anyone would know where to stand to get wet or to stay dry. The shape of the water column of the fountain is analogous to the shapes of atomic orbitals – the shape of the atomic system’s strange attractors.

This metaphor can be applied to complex social systems. Learning or behavior may not be precisely predictable, but it is likely to occur within some definable boundary. For example, in a classroom discussion, it is impossible to predict exactly what each student will say, but productive group interactions are expected to be bounded by the subject matter, the norms of the class, or general rules of politeness.

Many social theorists (notably Gilstrap, 2005; Senge, 2000; Wheatley, 1992) suggest that the most effective force that keeps social systems together is “shared meaning.” ³ A better name might be “group-held meaning,” since the meaning may not be

³ Though these authors use different terms, they all describe what Gilstrap calls “shared meaning.”
shared by every individual within the group, but rather that the group is sufficiently interdependent, there can be such a thing as group meaning (Stacey, 2003). They contend that if the entire organization is truly committed to some mission, each member will, without significant further instruction, act in some way that is not strictly and precisely predictable, but consistently points toward that mission. One good example of this is the mentoring of new teachers. Whether or not a new employee is assigned a formal “mentor,” there are people in the organization who will fulfill that role without being instructed to do so. Often a teacher will have one mentor in the area of computing, another in classroom management, one in inter-faculty relations, and others. If the organization truly has a vision held in common, these diverse mentoring experiences, when combined together, will lead the new teacher in one trajectory – toward the organization’s shared vision.

As a result of this bounded nature, systems can maintain themselves even as their component parts change (Bloch, 2005). A good example is a high school such as Metropolitan Catholic. Though students and faculty come and go, the strange attractor of shared vision allows the school to maintain its identity for hundreds of years, well beyond the lifetimes of any of the component agents. Even more interesting than the shapes of the strange attractors themselves are the forces that define the boundaries of these shapes. These are often called control parameters (McQuillan, 2008; Williams, 1997). The study of the boundaries of the strange attractors in these classrooms has combined descriptions of the forms these strange attractors take with the far more interesting examination of what forces (or control parameters) influenced the classes to take certain forms (strange
attractors). Because of the somewhat cumbersome nature of the language of mathematics, this study described the forms of the strange attractors as “bounded spaces” or just described their “boundaries,” and the control parameters have been described as “forces,” “influences,” or other related terms.

**Synergistic**

The powerful result of having a *well networked, nonlinear, bounded* complex adaptive system is that it can be more than the sum of its parts (Robinson, 2005). Whether this is called autopoiesis (meaning, literally, to create one’s self) (Capra, 1996), the formation of dissipative structures (Polite, 1994; Smitherman, 2005), self-organization (Carr-Chellman, 2000; Clarke & Collins, 2007; Davis & Simmt, 2006; Doll, 1989; Livneh, 2005), or emergence (Harkema, 2003; Johnson, 2001; Robinson, 2005), the central message is the same. Complex adaptive systems can adapt of their own accord. This distinguishes them from complicated systems, such as machines, which can not adapt on their own. A car is complex only in the colloquial sense, in that it is composed of many interconnected parts, but it does not *adapt* to new environmental conditions. A sports car, for example does not transform itself in to an off road vehicle when it comes upon a dirt road. Complex adaptive systems, however, such as individual living things, organizations (like schools or classrooms), or ecosystems, *respond* to stimuli, and adapt to make themselves better suited to their environments. A commonly used example is the anthill, which becomes a food gathering system when food is abundant or a war-waging system when threatened. The entire system responds to its
Emergent Learning

environment and adapts to make it best suited for the situation in which it finds itself at that moment (Johnson, 2001).

Emergent Learning

If the learning community most often called “a class” is a complex adaptive system, the central goal of this dissertation project will be to determine whether learning is an emergent phenomenon that results from the synergy of a well networked, nonlinear, bounded group of high school students and their teacher. Can the interactions of members of a group result in new knowledge – not theretofore present in any agent of the system (students or teachers) – being generated by the group, and will that knowledge then feed back upon the students to result in individual learning?

The assertions of a number of theorists seem to indicate that emergent learning is a natural function of complex adaptive systems. Davis and Simmt (2006) contend that “complexity science deals with self-organizing, self-maintaining, adaptive phenomena – in brief, with systems that learn” (p. 295). This theoretical conflation of complex systems with the ability to learn is echoed by Margaret Wheatley (1992), who calls complex adaptive business systems “learning organizations.” David Pines (1998), who is affiliated with the Santa Fe Institute – an independent organization of complexivist researchers from fields as diverse as physics and sociology – has even gone so far as to suggest that “learning itself is a complex adaptive system” (p. 7). This study is not so ambitious, choosing instead to portray one type of learning as an emergent property of a system
known as a class. Nonetheless, these theorists imply that classroom communities should be (or should be able to become) complex adaptive systems.

**Complexity Theory as Confluence**

As a genuinely transdisciplinary field, complexity theory is not the descendent of any single predecessor, but rather represents a confluence of wisdom accumulated from many otherwise separate disciplines. As intellectual revolutions have swept through fields as diverse as theoretical physics and Freudian psychology, they have all pointed in the same direction: away from simple, linear, cause and effect thinking and towards well networked, nonlinear, bounded phenomena with emergent properties.

**The Natural Sciences**

Complexity theorist Margaret Wheatley (1992) has observed, “Intentionally or not, we work from a world view that has been derived from the natural sciences. But the science has changed. If we are to continue to draw from the sciences . . . then we need to at least ground our work in the science of our times” (p. 6). The late nineteenth and early twentieth centuries brought a genuine sea change in both the life and physical sciences.

In the first few decades of the twentieth century, sometimes called “the thirty years that shook physics” (Giberson, 1989), nonlinear thinking would come to dominate the physical sciences. This change was so dramatic that academic study of this field is now divided between Classical Physics (developed by Isaac Newton in the seventeenth century) and the Modern Physics of today. Newton’s interpretation of physical phenomena was rooted strongly in the “if . . . then” logic of linear thinking. Examples of
Newton’s Laws of Motion, for example, might read as follows. If one throws a ball into the vacuum of space, then it will fly in a straight line forever, until it encounters another force. If two balls, one with twice the mass of the other, are dropped from an equal height, then the heavier one will exert twice as much force on the ground. Finally, if one hits a brick wall with a car at 30 mph, then it will exert the same force as if a wall moving at 30 mph had hit a stationary car. In a Newtonian world, linear thinking reveals a comfortingly predictable world.

As scientists began to look at smaller and smaller particles, however, they realized that Newton’s laws ceased to apply. For example, classical physics uses separate sets of laws for particles and for waves of energy. As scientists peered into the atom, however, they discovered that electrons behaved as if they were simultaneously particles and waves. This inspired Werner von Heisenberg to conclude that one can not simultaneously know the position and direction of motion of an electron. This is completely antithetical to the tidy, predictable world of Newtonian physics. The ultimate expression of this kind of nonlinear thinking is found in a thought experiment proposed by Erwin Schrödinger. His thought experiment began by putting a cat in a box, hiding it from view. An outside observer then pressed a button that either administered poison to the cat or didn’t; there was no way to know which. The question was, of course, “Was the cat alive or dead?” In the quantum world, Schrödinger suggested that, until the cat was observed, it existed as an infinite number of, “waves of potentiality.” It was simultaneously alive, dead, dying, escaped from the box, or any number of possibilities. Only when the cat entered into relationship with an observer (for example, if one lifted the box and looked inside),
would all of the waves of potentiality collapse into a single reality (Wheatley, 1992). This example of waves of potentiality was meant to act as a metaphor for how electrons behaved. Despite its deterministic Newtonian roots, Schrödinger’s brand of radical non-linearity has become the defining characteristic of Modern Physics.

Environmental science has also made significant contributions to complexity thinking by providing richer descriptions of the power of diversity and ecological complexity. Another contribution, however, can be found in embracing of one of its core concepts, “systems theory.” Incorporated by some educational theorists as a paradigm in its own right (notably Fullan, 2005; Senge, 2000), systems theory advocates studying phenomena at the systems level, or, as Davis and Sumara (2006) would say “at the level of their emergence.” Also, it is from systems theory that complexity gets the concepts of feedback loops and autopoiesis (Capra, 1996).

In biology, the influence of Charles Darwin’s *Origin of Species* can hardly be overstated. Darwin did not introduce the idea of evolution. Scientists such as Jean-Baptiste Lamarck, who had been dead for thirty years by the time Darwin published his famous tome, had already suggested that current species represented altered versions of previous ones. Lamarck’s evolution, however, relied on a kind of purposefulness that would be missing from Darwin’s version. Lamarck believed, essentially, that changes occurred in individual organisms *because* of their environments. For example, a deer-like creature might stretch its neck to feed on tree leaves. Its offspring, born with longer necks, would then stretch farther, and so on, until what was once a species of deer became a kind of giraffe. Naturally, Lamarck’s theory was eventually dismissed, since it
is clear that organisms do not generally pass on traits to their children that have been acquired during their lifetimes. A bodybuilder’s children, for example, are not born muscular.

Darwin’s theory removed the determinism from evolution. He suggested that mutations occur completely at random, following no particular logic. Once mutations occurred, however, natural conditions would then determine whether or not the mutation would persist in future generations. The introduction of this kind of nonlinear process, with random events being bounded by a strange-attractor-like system (natural selection) that resulted in an emergent reality (the creation of new species) had a profound effect on the way people saw natural processes. No longer could one assume that the world was a carefully controlled, deterministic place. This revelation would spread outward from biology to affect many areas of human thought.

**Philosophy**

Clearly, John Dewey would have agreed with Wheatley’s (1992) call that our work be based upon the science of our times. In 1909, before the revolutions in physics, mathematics and environmental science, the world was just beginning to realize the philosophical implications of Darwinian evolution. Urging philosophers to recognize the consequences of Darwinism, Dewey (1909) penned “The Influence of Darwinism on Philosophy.” Like Wheatley, Dewey lamented that philosophers were late in adopting this new, less deterministic, worldview. Building off of this influence (among many others), Dewey and others put forth the philosophy of pragmatism. According to
complexivists Davis and Sumara (2006), “truth, the world, and existence, to the
pragmatist, are understood as sorts of collective fantasies. They are contrivances in which
we all participate and to which we all contribute” (p. 73). Complexity theorists expand
upon this notion, adding that these contrivances are not only held individually, as
influenced by those around us, but that they can actually emerge at the group level.

Drawing not only from the pragmatists, complexity theorists also have much in
common with a variety of postmodern discourses. Presented in Pinar et al.’s, (2004)
mammoth tome on all things curriculum-related as the personification of postmodern
curriculum theory, William Doll Jr. (one of the authors whose empirical work will be
reviewed in Chapter Two), advocated a shift from a modern perception, characterized by
such classical-physics-inspired tenets as “for every effect there is an a priori cause since
we live in a closed mechanistic universe” (Doll, paraphrased in Pinar, Reynolds, Slattery,
& Taubman, 2004, p. 500) to a postmodern view, based on biology “with its concepts of
complexity . . . and network relations” (Doll, quoted by Pinar, Reynolds, Slattery, &
Taubman, 2004, p. 500) and chaos theory, which recognizes that “curriculum needs to
have the right amount of indeterminacy, anomaly . . . chaos, disequilibrium, dissipation,
[and] lived experience” (Doll, quoted by Pinar, Reynolds, Slattery, & Taubman, 2004, p.
501).

Mathematics

Benoit Mandelbrot’s (1982), The Fractal Geometry of Nature, is widely credited
with bringing fractals into the popular consciousness. As elucidated above, this
mathematical principle provides a metaphor which complexivists use to frame the nested nature of complex adaptive systems. Quickly, fractals became incorporated into the mathematics of chaos theory, which in turn contributed the concepts of strange attractors and the butterfly effect. As is the case with systems theory, some educational theorists and empiricists have chosen to frame their work in the language of chaos theory (i.e., Doll, 1989; Polite, 1994).

\textit{Psychology and Learning Theories}

From the time of Plato, through Descartes and into the twentieth century, psychology held that there was a strict separation between the knower and that which could be known. Perception was seen as a barrier between learners and ‘the truth,’ a membrane separating the knower from the known. At about the same time that Schrödinger, et al., were revolutionizing physics, however, Sigmund Freud and Edmund Husserl were transforming psychology. Among the contribution of Freud’s psychoanalysis was the idea that the individual’s constitution of the world and the world’s constitution of the individual could not be separated. This kind of intimate co-creation is echoed in complexity theory’s understanding of reflexive processes and interobjectivity. Husserl’s phenomenological theory echoed this sentiment, describing a complex interweaving of concept and precept (Davis & Sumara, 2006).

These insights represent some of the philosophical foundation of the educational theory of constructivism. Constructivism recognizes the agent’s role as an active participant in the learning process, independently constructing realities that are not
dictated strictly by a teacher. For constructivists, information is not an unalterable, abstract object that is simply passed on to a student. Rather, learners actively create perceptions of the world based on their own experiences (Phillips, 1995). This parallels the complexivist assertion that independent agents are required in order to form learning organizations (Ollhoff & Walcheski, 2002). An active agent in a complex adaptive system is one who is able to independently construct knowledge, and then provide that insight to the system. Building upon the constructivists’ vision of individual learning, Soviet psychologist Lev Vygotsky and his followers added the conviction that learning was not only a matter of individual construction, but was a social act. Students did not simply construct new understandings by observing things in the world, but did so with guidance provided by their social interactions (Hedegaard, 2007). Clearly, this is compatible with the kind of networking that complexity theory highlights. In complex systems, students, possessing true agency, can enter into social situations such as well-networked collaboratives to produce emergent learning.

The Unique Contribution of Complexity Theory

The defining contribution of complexity theory is the idea that systems can produce synergistic results. Though the researchers who have contributed to other theories have recognized that education is a social act, most have retained a vision of education as the acquisition of new knowledge or a new level of development. In contrast, complexity theory allows for the possibility that a group may actually generate new knowledge.
In the mind of, for example, Vygotsky, the social systems in which a student learned contributed to that learning. Though the social learning theories he fathered are in most ways compatible with complexity thinking, Vygotsky tended to present society less as something co-created by the student but more as an external force, contributing to a child’s development. This perspective was epitomized by one of Vygotsky’s major contributions to educational theory, the “zone of proximal development.” He defined this as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). In this perspective, children were made apprentices to a relatively static society (particularly through interactions with more knowledgeable members thereof). Vygotsky held the common belief that learning represented “a process by which children grow into the intellectual life of those around them” (Vygotsky, 1976, p. 88). Rather than as a static given, some complexivists think of the group (an example of a society) as the actual organ of learning. As Davis and Sumara (1997) suggested, “Cognition does not occur in individual minds or brains, but in the possibility for shared action” (p. 105). It is for this reason that the grain size of this study has been at the group level, rather than focusing on individuals.

More than simply changing the unit of analysis, however, complexity theory allows for the possibility that rather than viewing learning as a process of apprenticeship, it can, under some circumstances, become a process by which a group of people can be the source of new knowledge. Other social learning theories emphasize how groups may
be used to acquire knowledge, and this is a laudable goal. In complexity theory, however, there is a particular mindfulness of the fact that the individual and the group are engaged in a constant process of co-creation. The child is changed by her or his social interactions with the group while the group is simultaneously changed by the membership of the child. Because of this constant recursion of co-creation, complexity theory allows for the particularly exciting possibility, rarely discussed in any other framework, that groups of students may create, rather than simply be apprentices to, new knowledge.

Conclusion

The idea that complex adaptive systems are well networked collectives of discrete agents that are nonlinear, bounded and synergistic is derived from a number of different sources. It draws, first of all, on the intellectual revolutions that happened, often simultaneously, in the natural sciences, psychology, philosophy, and learning theory. Drawing upon the wisdom accumulated in these disciplines, complexity theory has emerged as a way of thinking about systems in these fields, as well as in others, such as management theory (Wheatley, 1992). Recently, complexity thinking has been applied to educational systems, and is now beginning to be regarded as a way to view what happens in classrooms.

The version of the definition put forward in this chapter, though applicable to complex systems of many kinds, has been crafted specifically to speak to the classroom system. For example, a leadership theorist, who is likely to be interested in power dynamics, might talk about empowerment of workers, where this researcher speaks of
agency. Someone interested in leadership might also advocate for the removal of hierarchies, where this study was framed in terms of Davis and Sumara’s (2006) centralized, decentralized and distributed networks. All of the same concepts are present; it is simply a matter of emphasis. Since this is a study focused on learning, the definition of complex adaptive systems used in this work speaks to emergent learning in the classroom.
CHAPTER TWO – MANIFESTATIONS OF COMPLEXITY IN THE CLASSROOM

Very little empirical research has been directed at examining the classroom environment from the perspective of complexity theory. Since at least 1989, however, some researchers have taken an interest in the complexity of groups of students ranging from kindergarten-age through graduate school. Drawing upon the concepts elucidated in chapter one, this chapter will highlight how each of the available studies has cast light on each of the major characteristics of complex adaptive systems. An overview of the research community and critique of the current state of the field will follow.

Importance of Empirical Research

Though theorizing is a tool crucial to the advancement of human understanding, it is important to practitioners and their students to determine whether conceptual theorists’ vision of what could be, or what should be, actually manifests itself in the classroom environment where we must work. Complexity theory makes sense to me, and to the many theorists working in this field. The fact that something makes sense, however, simply does not guarantee that it can be found in the “real” world of classrooms and students.

To draw an analogy from another discipline, it is sensible, for example, that, since the sphere is such an important shape in astronomy (most of the large objects in the solar system, for example, are roughly spherical), planets should move in circular orbits around the Sun. Greek philosopher Ptolemy even devised a complex explanation of spheres rotating around spheres to explain the phenomenon of retrograde – when a planet begins
crossing the sky in one direction, reverses for a time and then continues on its original course. His calculations were elegant, sensible and largely wrong. When empiricists took a closer look at the movement of celestial bodies, they found that the planets have elliptical orbits and that retrograde is due to the fact that planets in the part of the ellipse closer to the sun move more quickly than those that are far away (Giberson, 1989). Likewise, in education, if we do not closely and rigorously examine the classroom environment we are in danger of generating theories that are elegant, sensible and largely wrong.

Criteria for Inclusion

Because of the importance of empirical touchstones for philosophical work, research included in this section must have involved disciplined, direct contact with research participants. Much theoretical work *alludes* to classroom or organizational experiences, but does not attempt to provide examples from specific situations. Only explicitly empirical work has been included in this examination. Also, because the focus here is on classroom research, only “classroom situations” are considered. As such the stated purpose of the group being studied must be to learn something, as opposed to work groups that are assembled to solve a problem or make a plan. Though there is a good case to be made that an integral part of utilizing the power of complex adaptive systems in work groups is to make them into “learning organizations” (Wheatley, 1992), and that good learning involves solving authentic problems, this study examined groups that were assembled in school settings for the primary purpose of learning, so those are the groups
that are included in this paper. Not only are learning groups unique, they are uniquely important, as they represent a site of praxis in educational research. Though the quality of the studies described herein varies widely, all articles that appeared to report on empirical research in classroom settings have been included in an attempt to provide for the reader the broadest possible view of the current research on classroom complexity. Critiques of these studies will be included to assess their overall quality and applicability to the research described in this dissertation.

This section represents an attempt to assemble a representative sample of empirical research conducted in classroom environments that dealt explicitly with complexity theory. Though many researchers have made conclusions that parallel those of the complexivists, studies that did not mention complexity (or the closely related chaos theory) by name were avoided so that the findings represented here will revolve around those of the actual researchers, not exclusively on this author’s post hoc interpretations of other people’s work. Toward that end, keyword searches of the ERIC database were conducted using terms such as “complexity theory” and “chaos theory.” Title searches were also performed using the word “chaos” and also “complexity.” Google scholar “who cited” searches were also made on each of the resulting articles, as well as on the theoretical books cited in this proposal. The bibliographies of these books and articles were then also scanned for appropriate articles. Finally, a title search of the journals Learning Science (which counts complexity among its topics of interest) and of Complicity: An International Journal of Complexity and Education, which, as the title suggests, is dedicated entirely to complexity theory was performed. The last ten years of
Learning Science was searched, while all issues of Complicity were examined, since this journal has only been published since 2004. Though it would be hubris to assume that any literature review could address every relevant article, these systematic search and selection methods were designed to ensure, to the greatest degree possible, a reasonably representative sample of the available literature.

Empirical Research on Complexity in the Classroom

As has been emphasized ad nauseum, complex adaptive systems are well-networked collectives of discrete agents that are: nonlinear, bounded and synergistic. This section will examine how each of the twelve empirical studies included in this review contributed to the evidence base for each of the points of this definition. A table of information about the articles, arranged alphabetically by first author, has also been included (Appendix B).

Well-Networked

Inevitably, even systems that will one day act as collectives must begin as mere collections of disconnected agents. Davis and Sumara (2001) had the opportunity to observe a collection of people gathering for the first time and to study the process of network formation. They were hired to facilitate discussions among members of a new faculty composed of veteran teachers who had never worked with each other before.⁴

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⁴ Though this was a workplace group, Davis and Sumara were hired to facilitate group sessions in which teachers would learn about current research. Since their observations were made in this context, I have categorized this as a “classroom situation,” qualifying it for inclusion in this review. They wrote another
Poor student achievement and increasing parental complaints encouraged the local school board in one Canadian community to completely disband the previous faculty and replace it with a new one, assembled by taking teachers from other parts of the system. Davis and Sumara observed that these teachers, unfamiliar with their surroundings, began their time together by framing issues in genuinely individualistic terms (Pines, 1998). Examination of transcripts of the researchers’ sessions with groups of teachers revealed that, early on, conversation was dominated by “I” statements. As time went on, however, Davis and Sumara observed change in the discourse from the domination of “I” statements to a balance between “I” and “we” statements. They asserted that this observation indicated that the faculty was beginning to form a network (my word) rather than a collection of individuals.

In a more recent study, Davis partnered with Elaine Simmt (2006) to study a group of 26 Canadian mathematics educators who represented a broad range of experience levels and grades taught. Two were math specialists, while the others were general education teachers. The researchers facilitated a number of day-long professional development seminars, held every few months over an unspecified number of years, encouraging the teachers to work in small groups to solve mathematics problems of the participants’ own choosing. Davis and Simmt’s observations of the learning process influenced them to conclude that:

[B]ecause of its dynamic and nested character, mathematics-for-teaching [the process of having teachers solve math problems that are new to them as a tool to

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article alluding to the same group (Sumara & Davis, 1997), but the 1997 article is primarily dedicated to action research theory and neither contradicts nor adds to the 2001 findings, so it is not included.
understand how to teach math] cannot be considered a domain of knowledge to be mastered by individuals. It always occurs in contexts that involve others. (p. 309)

It is worth mentioning that Davis and Simmt’s conviction that effective networking involved short-range interactions caused them to pay careful attention to the structure of the network. They noted, in particular, that the “neighbor interactions” that they observed were not always based on the physical grouping of students in the class, but rather, “neighbors in a knowledge-producing community are not physical bodies or social groupings. Rather, the neighbors that must ‘bump’ against one another are ideas” (p. 312). In order for this bumping of ideas to work, they highlighted the tension between healthy diversity and sufficient redundancy by observing that “not only must there be neighbor interactions, there must be a sufficient ‘density’ of such interactions . . . to ensure that ideas can play off one another” (p. 312).

Also concerned with the interplay of diversity and redundancy was Margaret Sinclair (2004). This is perhaps not surprising, as she was inspired to conduct her study after reading one of Davis and Simmt’s earlier works. In addition to her interest in their assertion that “mathematics classes are adaptive and self organizing complex adaptive systems” (quoted in Sinclair, 2004, p. 57), she used their ideas about what conditions allow for innovation within a system as a framework for her observations. Rather than observe adult learners engaged primarily in paper-and-pencil problem solving, however, she chose to study three cases involving Canadian secondary school students who were using different types of software in a computer lab setting.
Sinclair’s first group was composed of students in her Ontario Academic Credit (OAC) course in algebra and geometry. OAC was a now-discontinued university preparation program. These students were assigned the task of learning about linear transformations by using a spreadsheet program. Her second group, composed of three grade-twelve classes from two different schools, utilized JavaSketchpad to generate web-based dynamic geometry sketches in senior mathematics. Finally, she related the experiences of OAC students over the course of four years who were engaged in an independent study project. These students, working in the computer lab after school or during lunch, were given the choice of using a spreadsheet, JavaSketchpad, or math software known as Maple V to investigate a number of classic mathematics problems (including, for example, the Pythagorean theorem and Koch’s Snowflake).

She found that the diversity of computer experience present in her classes allowed for a high level of experimentation with the programs that the students had available to them. As students shared their individual areas of expertise they “discovered so many new possibilities that [she] was taken aback” (p. 62). In one case, this diversity was complemented by the redundancy inherent in her students’ shared knowledge of algebra. This common starting point allowed students to share their diverse knowledge of computer use to do the mathematical tasks. In her geometry class, however, she found that this kind of redundancy was not present. Enough students lacked strong enough geometry backgrounds in order to produce a common terminology. This proved to be a stumbling block. Reflecting on the different kinds of networking that she saw across the three cases, Sinclair noticed that the independent study project, with its more informal
feel and free association among group members, produced a natural error check as groups shared across the room. In the other classes, where she did not permit students to work with other pairs, a strong link between members of each pair was forged, but the benefits of a wider network were squelched.

Another study involving mathematics students engaged in group-focused tasks largely independent of the teacher was conducted by William Doll in 1989. The earliest application of complexity theory to the classroom environment by a full eight years, this article described a co-teaching situation in which Dr. Doll worked with a sixth grade American mathematics class once a week for the entire 1987-1988 school year. Certainly because he was teaching about nonlinear mathematics, and perhaps because the language of complexity theory had not yet been developed to its current level, Doll described this learning community in the language of chaos theory.

Inspired by the properties of fractals, Doll and the class’ regular teacher (Ron) designed their Friday classes based on two elements of chaos theory: boundaries and an attractor area. Given this inspiration, they structured the class by dividing students into groups of two or four and then allowing them to solve problems (developed by Ron) in their own way and largely in their own time. Though they did not use this terminology, what Doll and Ron were doing was to give agency to the students. Rather than being passive receptors of knowledge, each student was instead treated as an independent thinker, and was therefore able to make contributions to the collective thinking in their

5 The aspects of this study that demonstrate strange attractors will be discussed in the section on boundaries below.
small groups. Because they were in groups, they were then able to network those ideas, using the synergistic results to devise their own ways to solve unfamiliar problems.

Each of these studies challenged the conventional notion that a class was simply a collection of individual learners, each interacting primarily with the teacher, and otherwise learning as if he or she was alone. In these studies, learning was not viewed as if it were an exercise in tutoring many students as once, but was instead a true group activity. Well differentiated agents networked with one another to work together to construct knowledge.

**Nonlinear**

Doll’s (1989) study also highlighted a nonlinear aspect of complex adaptive systems; they operate far from equilibrium, or at the edge of chaos. Doll sought to remove students from their passive roles and structure the class in such a way that they “had enough of a ‘burr’ to stimulate the students into rethinking their habitual methods” (pp. 67-68). As a result of this perturbation, and of the decentralized network structure of the group work, “whether an observer saw randomness or progressive order depended on whether that observer was in the class for a few minutes or for the whole class period” (p. 66). Doll and Ron had set up a system that looked like chaos, with the faith that it would generate a new order.

Doll’s work serves as a reminder that identifying attractor areas in complex systems requires significant effort. In mathematics, the concept of the fractal, for example, was not developed until computers were available that were capable of running
countless iterations of complex mathematical formulas. Because humans can not calculate fast enough to do so many iterations in a lifetime, all of fractal geometry remained hidden until more fully developed mathematical systems could be observed (Davis & Sumara, 2006). The calculation of just a few iterations of an equation is analogous to trying to observe complex classroom systems using snapshot-like momentary observations. Take the example of bees in flight. Bees communicate with each other by flying in various patterns (for example, a figure eight). If one took a snapshot, or even a few snapshots, of this behavior, it would be nearly impossible to determine what was going on. By observing the bee over time, however, and by looking not only at the entire dance but by observing the response of the rest of the hive (the system), one can determine whether the hive is being called to mate, to gather food, to defend the hive, or to do any number of other things. In order to see complex behavior, the researcher must take a holistic view and observe the system as it develops over time. So, Doll suggested, it was with classrooms. He claimed that if one simply glanced into his classroom, it would appear to be in utter disorder. Further observation, however, would have revealed the pattern of learning emerging from the edge of chaos.

Another study concerned with systems that operated at the edge of chaos was Zellermayer and Margolin’s (2005) study of 15 Israeli student teacher supervisors. With Margolin as department chair and Zellermayer coordinating research, they embarked on a three-year process aimed at constructing a professional learning community. This process included a new expectation that both student teachers and their supervisors would be engaged in action research projects as part of their experiences. Beginning with the
second year of the overall project, practicum supervisors ranging in experience from two
to thirty began meeting on a weekly basis to learn about action research and to
discuss their work. This was a genuinely contentious process, with support for the
changes ranging from a group of five who supported the process and conducted action
research projects, to the rest, who “created a ‘shadow system’ that met in the college’s
lounge on a regular basis before the official meetings began, because they felt that the
‘official’ policies were in conflict with their approach” (p. 1281). Using transcripts,
interviews and reflective notes, the researchers identified four critical incidents which
they describe in the article. Each was an example where a supporter of the new system
presented her action research project, while others responded with support, concern, fear
and/or principled disapproval. According to Zellermayer and Margolin, this sustained
disagreement was healthy from the perspective of complexity theory, since
 creativity in adaptive systems occurs in a special zone between the unstable
 disorder of chaos and the stability of no change at the edge of chaos . . . This
 essential creative state must be sustained long enough to overcome the tendency
to revert to the safe, stable patterns of the past. (p. 1279)

Davis and Sumara (2001) agreed, suggesting that one factor that made change
possible in the school with the reconstituted faculty was that teachers were prepared to
embrace some level of conflict as being indicative of a healthy state, far from
equilibrium. “Rather than attempting to eliminate difficulty or unexpected occurrences,
the teachers in this school began to see these as necessary to a healthy, developing
learning system” (Davis & Sumara, 2001, p. 93). These teachers had little choice. They
had been removed from their previous assignments and thrown together in this reconstituted school. The existence at the edge of chaos and the cognitive dissonance were inevitable. Their decision to embrace this state was the defining characteristic of this group.

According to Zellermayer and Margolin, “the dissonance, caused by a clash between positive feedback . . . and negative feedback . . . delineates the learning space for the group between disintegration and chaos, where creativity can emerge” (p. 1300). But feedback can do more than hold systems at the edge of chaos. Anthony Clarke’s team at the University of British Columbia (Clarke, Erickson, Collins, & Phelan, 2005) presented a less contentious example of feedback at work in the pre-service teaching realm. They related the experiences of 36 pre-service elementary teachers who were participating in an alternative to the University’s normal teacher training curriculum. This program, known as CITE (Community and Inquiry for Teacher Education) was a 12 month post-degree Bachelor of Education elementary program that used a cohort model, expecting all members of the community to chair meetings; contribute talent, resources and time; and be attentive and responsive to the needs of the community. To enhance this sense of community, students were clustered into groups of six per elementary school for their practicum experiences.

This commitment to networking produced a situation where information could be fed back for the purpose of enhancing learning. A favorite activity of one of the researchers who also served as a social studies methods teacher was called “who packed the pack.” The professor brought in his wife’s backpack, stuffed with things that she (an
elementary vice-principal) used for off-campus excursions with students. He spilled the contents out and distributed them around the room. Normally, he had observed that students outside of the CITE program had been hesitant to share information with other groups within the class. In the CITE group, however, small groups began to interact and a collective sharing of artifacts and tentative theories began. The researcher found that the CITE group’s interaction allowed them to quickly identify the real owner.

It appeared that the spontaneous networking of the class allowed information to be fed back over and over again over the course of the exercise, which permitted a quick solution. Information was more than shared, it was mutually reinforcing. This kind of recursiveness was supported by the authors’ proposition that “as we write the text, the text writes us . . . every interaction, however small or insignificant, is determined by and determines the quality of the learning environment that is created” (pp. 172-173). This study demonstrates how nonlinear interactions allow for unexpected outcomes.

Two members of the same research team (Clarke & Collins, 2007), later shared their observations of a highly experienced kindergarten teacher who regularly supervised pre-service teachers in their programs. In Nadine’s class, “There is a network like structure to the way the classroom is organized or web-like pattern that encompasses a range of possibilities for interaction” (p. 165). As an example of feedback in the classroom, they related a humorous story about one class’ fascination with the clothing of one of the researchers. One day, Tony Clarke went to this kindergarten class wearing shorts, sandals and carrying a camera. A student asked, “Are you going to the beach?” Rather than squelch this interaction, Nadine held back as students shared various theories
about who he was. Occasionally, Nadine or her student teacher would interject briefly so as to help a student who was searching for the right word or to ask a probing question so as to add depth to the conversation, but they mostly allowed the interaction to follow its own course. Clarke and Collins presented this as an example of feedback. The conversation not only served to generate an answer as to who Clarke was, but also provided ancillary benefits. For example, as the conversation went around, it became clear that one of the students had rarely been to the beach or swum in the ocean. This helped the student teacher to understand why this pupil had difficulty with a recent unit on the seashore. Davis and Simmt (2006), reflecting on their study of math teachers, observed similar phenomena, concluding that “with a focus on recursive elaboration rather than accumulation or simple elaboration, each successive iteration of an idea is about expanding the space of possibility (p. 308). In both studies, nonlinear networking allowed the recursiveness required to discover new possibilities.

Davis and Sumara’s (2007) most recent work cast additional light on “expanding the space of possibility.” This article related their experiences teaching methods classes at a Canadian university. Sumara’s 32 English methods students were given the assignment of writing a poem. Rather than simply telling them to “write what they felt,” which is the way they had often been taught before, Sumara set up a series of stimuli that both provided enough of what Doll (1989) called a ‘burr’ to get conversations going, and enough recursiveness and successive iterations to produce emergent results. He gave each student a button and asked them to think of an article of clothing and then of a person who would wear it. Students then paired up and shared their imaginings. They were then
instructed to think of an interaction between the two imaginary people. Finally, each group was given a photograph, asked to guess what happened just before it was taken, and sent off to write poems together for homework that were based on their classroom work and modeled after the style of a famous poet. At least one student remarked, “It’s interesting how our final poem developed on the screen. I don’t think that either of us could say who wrote what” (p. 62)

One of Brent Davis’ favorite activities (it is also described in Davis & Simmt, 2006) was to ask students the question “What is multiplication?” At first, it seems like there would be an obvious answer, particularly among a group of math educators (or, in this case, future math educators). Davis insisted, however, that groups of students look more deeply into their initial definitions. Again, as students fed inputs into the system, new insight was fed back. After 20 minutes, all of the groups were still hard at work, and most had filled their sheets with possible definitions. In the end, they concluded that “multiplication seemed to be a sort of nexus – a complex and continuously modified blend of actions, analogies, and formalizations” (Davis & Sumara, 2007, p. 63).

In these studies, learning was not a passive act. Indeed, it was often characterized by a certain level of intellectual discomfort, what Thompson and Zeuli (1999) have called “cognitive dissonance.” In the language of complexity, cognitive dissonance comes from being in a state far from equilibrium, at the edge of chaos, where disturbing a system’s normal patterns (by, for example, redefining comfortable terms like “multiplication” or introducing faculty to a new mentoring model) sent the system into a state where it was forced to utilize feedback loops and other nonlinear information processing patterns to
reevaluate its old conventions, and to consider new ways of doing things. In short, it was stimulated to learn.

**Bounded**

Another theme addressed in the empirical literature was that of the strange attractor. Though not all researchers used this term, it is clear that a number of studies have shown that learning in classrooms, though nonlinear, nonetheless exhibited definite boundaries. Just as the seemingly random movement of water droplets out of a hose results in a definable shape, so do the seemingly chaotic actions and perceptions in a classroom result in definable strange attractors.

A particularly astute reader may recall that Doll (1989) and Ron’s sixth grade mathematics classes were based not only on providing a nonlinear experience for well differentiated students, but were also structured around the ideas of boundaries and a strange attractor area. Though Doll was not explicit about describing the strange attractor in his classroom, he did say that he became aware that over the period of the 45 to 60 minutes a new type of order was emerging – progressive, constructive, personal, interactive . . . Ron and I virtually never had to admonish students to finish. While the process seemed disorderly from a segmented view, it had a unity found only by looking at the *whole* class during the *entire* period. (p. 66 italics from the original)

This emergence of a new order indicates that some boundaries had spontaneously formed. The learning community, though it had altered its existing paradigm by creating
a more chaotic classroom structure, nevertheless spontaneously created new boundaries for itself. It had formed a strange attractor.

Davis, Sumara and Simmt (Davis, 2005; Davis & Simmt, 2006; Davis & Sumara, 2007) often highlighted the changeable nature of boundaries when they spoke of learning in terms of the “space of the possible” and its expansion into the “not-yet-imaginable.” These concepts bring to mind the idea, incorporated into complexity from chaos theory, of the strange attractor. What they were describing as the space of the possible was the set of conventions and preconceived notions that caused a group to think and act in a certain way. It is the original pattern of boundedness that existed before a change. After perturbing that comfortable space (moving the group away from equilibrium) a new paradigm (a kind of strange attractor) was formed: the space of the not-yet-imaginable. Though they did not use the words “strange attractor,” they described learning as trading one limited strange attractor state for a more expansive one.

Unfortunately, not all strange attractors represented a system that adapted in a way that most people would consider positive. Vernon Polite (1994) conducted a sweeping study of 115 African-American males from one high school (at which he was an administrator) that included 600 hours of observation; 242 semi-structured interviews with 65 of the students, 35 teachers and staff, and 35 parents; and an examination of official and unofficial documents. According to his analysis, demographic changes and unrest in the 1970s snowballed (as in the butterfly effect) to produce a system that was, at the time of his study, bounded by the strange attractor of student rejection of teachers whom they (and, in many cases, Polite) perceived as insensitive. Partly as a result, only
60% of these students graduated, and, even among those who did, they generally took the easiest available classes, choosing to take a random selection of “useless” electives, simply because they were allowed to do so.

In each of these cases, the systems being studied formed the kind of bounded conditions, or strange attractors, that were defined by what Gilstrap (2005) called “shared meaning.” Whether it was Doll’s (1989) students’ “new order,” Davis Sumara and Simmt’s (Davis, 2005; Davis & Simmt, 2006; Davis & Sumara, 2007) “space of the not-yet-imaginable,” or Polite’s (1994) “rejection of teachers” each system adopted a kind of group-held perception that ended up defining the boundaries of the system.

**Synergistic**

One learning community that counted among its central goals to create new boundaries for itself was a class studied by Steve Collins (2004). Taken from his dissertation work, this research was conducted before he joined Anthony Clarke’s team and contributed to two of the other studies reviewed above (Clarke & Collins, 2007; Clarke, Erickson, Collins, & Phelan, 2005). Collins’ 2004 work focused on responsibility and autonomy in the elementary classroom primarily from the perspective of participatory democracy. He described how such a democratic system was implemented in a class containing students in grades one and two, recounting how democratic organizational meetings met first once a week and then, eventually, every day. Sometimes chaired by an adult and sometimes by a student, Clarke explained how the class met to share concerns or make plans. One of the things emerging from this system
was a sense of self-organization, particularly as represented by their consensus-derived “Seven Strategies to Deal with Problems.” This set of guidelines became a touchstone upon which students often drew when offering suggestions to social problems within the class. As a self-imposed structure, this represented the emergence of a new level of classroom organization. More than just a boundary, this was a process that represented a true synergy – a collective accomplishment far greater than the sum of the constituent contributions.

Another example of student self-organization was provided by Laroche, Nicol, and Mayer-Smith (2007). They taught a group of nineteen pre-service teachers in an elementary science methods class. This class was split up into four groups, with each group being assigned ten elementary school students with which to work. The task was to work with these children to produce videos that demonstrated knowledge of some scientific subject. The authors asserted that the discomfort of the pre-service teachers, the large numbers of ideas put forward by the students, and the loosely organized nature of the activity were factors that maintained a state at the edge of chaos. Their end products (the videos), were put forth as examples of self-organization. “Through trial and errors, student teachers learned not to impose, but to guide the process of collective emergence; they learned how to adapt to the unplanned” (Laroche, Nicol, & Mayer-Smith, 2007, p. 79).

Working with most of the teaching staff of a small urban elementary school and occasionally co-teaching with some of them, Davis and Sumara (1997) saw a similar kind of emergent result in the classes they were co-teaching. They were on campus to engage
with the teachers in collaborative inquiry into the nature of learning, by gathering with the faculty in semi-monthly meetings. They found, however, that the project soon expanded, until both Davis and Sumara ended up co-teaching within their respective areas of expertise. Davis co-taught an introduction to fractions in a class that included students in third and fourth grades, while Sumara co-taught a unit on a popular novel in a grade five and six classroom. They sought out to model the complexity-theory-based philosophy of teaching that they called “enactivism,” which was, in part, based on the assumption that:

[W]hile we could present occasions that were rich with learning possibilities and in which we might participate with our students in the unfolding of understandings, we could not prescribe what would be learned . . . learning, for us, is thus occasioned rather than caused. (p. 115)

Having facilitated their classes with this in mind, they discovered that “it was not unusual for the activity in the classroom to take completely unanticipated but (in terms of the subject matter) appropriate turns. Insights would ‘spread’ through the room” (p. 115). There was a transcendence to this learning. Presumably neither the teachers nor the students entered the class with the idea that the class would develop as it did, yet these unanticipated events resulted in new knowledge. This was the kind of emergent knowledge that was sought in the three cases observed in this dissertation.

Similar observations of the emergence of group characteristics could be found across most of the studies described in this review. Davis and Sumara (2001) showed how a collection of teachers from around a school system transcended their own needs
and became a cohesive faculty. In much the same way, Doll’s (1989) sixth graders created a new classroom culture. This kind of group identity formation was what Zellermayer and Margolin (2005) were hoping for at the end of their study of faculty conflict. In terms of learning, a number of articles have documented students’ use of recursive, networked methods to develop a new understanding of mathematics (Davis & Simmt, 2006; Davis & Sumara, 2007; Doll, 1989; Sinclair, 2004). Finally, students participating in Clarke, et al.’s (2005) “who packed the pack” activity and in Helen’s kindergarten class’ discussion of Clarke’s wardrobe (Clarke & Collins, 2007) used the properties of complex adaptive systems to learn about an individual person.

The study that has addressed the idea of emergent learning most directly was written by Dalke, Cassidy, Grobstein and Blank (2007). They are, respectively, a feminist literary scholar, a psychologist, a biologist, and a computer scientist. Combining their understandings of complexity, they proposed an “emergent pedagogy. After making a case that the human brain was an emergent system, they put forth a number of principles to be followed in an emergent pedagogy, including:

• Both students and their teachers need to have space, opportunity, and room to ‘‘explore’’—that is, for active learning.

• Students and teachers are co-learners and co-teachers.

• Teachers have a distinctive role to play in assuring that all idiosyncratic learners are supported.

• What is essential is not outcome but developmental process.
• An important criterion for content selection should be its usefulness in facilitating exploration. (p. 116)

Using these principles, these researchers designed a course that used emergent pedagogy to teach about the power of emergence. Students in this summer institute learned about the emergent properties of ant colonies, did exercises where students would act out a story as it was being changed from time to time by the audience, and used computer idea networking devices such as wikis. The resulting emergence was the unpredictable and innovative curricula that were written by the students at the end of the course. Not only did the emergence of the curricula themselves demonstrate complexity, but the lessons themselves were designed to recognize the principles of complexity taught and developed in the course.

The possibility of synergy is the enticing part of studying complex adaptive systems. Systems that were simply well-networked, nonlinear and bounded might be interesting to think about, but they would be rather unremarkable. On the other hand, if learning communities could transcend the limitations of the individuals in the classroom to produce learning that would not be possible in isolation, this could have powerful ramifications for teaching and learning. It could mean, for example, that learning as a member of a class may often be more effective than being tutored – not just for the acquisition of social skills, but because well networked groups can actually produce knowledge that is not held by any of the individuals in the class. The first hints that this kind of synergy may occur in classrooms have been described in these studies.
Critiques

One More Study

Whereas eleven studies reviewed above had similar (though diverse) ideas about complexity theory, there is one article that took a significantly different tack. There are two reasons why Charles Nelson’s (2004) study of his students merits separate attention. First, he used a definition of complexity theory, taken from biologist John Holland, which had a very different emphasis from the constructions included above. Second, whereas other studies chose to describe learning as a class-wide phenomenon, giving individual student examples as illustrations, Nelson focused primarily on individual learners.

In his description of learning in a university class of international students for whom English was a second language, Nelson (2004) invoked Holland’s concept of “building blocks.” This was the concept that a few types of simple components can combine in such a large variety of ways that they would produce a very large number of possible results. Nelson cited Holland’s example of a human face. If one considers the face of being made of about ten building blocks (eyes, noses, and others), and then assumes that there are about ten different kinds of noses, eyes and other blocks, the result of combining these elements in every conceivable way would be about ten billion possible faces. Similarly, all of the DNA of every living thing on the planet is made of only four types of nucleotides. The vast number of possible combinations of these is so great, however, that it allows for the incredible diversity of life on earth, and the remarkable individuality among single members of each species. Nelson suggested that three ways of using educational building blocks also interact to provide a number of
possible outcomes. These were: reproduction (applying previous learning habits to a new situation), recombination (combining old habits with new ones), and replacement (adopting new habits). Though he provided examples of how his students did each of these, it was difficult to see how this applied to complexity theory as it is understood elsewhere in education. The explosion of possibilities described in the combination of building blocks evoked images of the nonlinearity of complex systems, but as he focused on individual students he did not describe them as complex adaptive systems in their own right, or present them as producing emergent results as a collective. The result was that, rather than appearing synergistic, his learning results read as if they were merely additive.

The Research Community

It is not at all uncommon when studying a particular area of education to find that one is reading a relatively small number of authors who tend to cite each other. This is a function of the fact that only a limited number of people will choose to study any particular aspect of education and that well respected works surface that are widely cited. In the case of complexity theory as applied to the classroom, however, the research community appears to be so small as to be almost a caricature of this situation. For example, Davis and Sumara, who are, individually or together, responsible for one third of the studies reviewed in this paper (Davis & Simmt, 2006; Davis & Sumara, 2001, 2007; Sumara & Davis, 1997), dedicated their most recent book to their “mentor and friend, Willam E. Doll, Jr.” (2006, p. vii), the author of the 1989 study of a sixth grade mathematics class. In turn, Anthony Clarke’s team, who were, individually or together,
responsible for one fourth of the empirical studies in this chapter (Clarke & Collins, 2007; Clarke, Erickson, Collins, & Phelan, 2005; Collins, 2004), used Davis and Sumara’s features of complex learning systems as a touchstone for their analysis of the CITE program (Clarke, Erickson, Collins, & Phelan, 2005). Margaret Sinclair (2004) used Davis and Simmt’s “necessary but insufficient conditions to be capable of innovation” as a framework for her analysis of students in a math lab. This now adds up to eight of the twelve studies reviewed.

It seems that research about complexity in the classroom revolves around Brent Davis and, to only a slightly lesser extent, Dennis Sumara. Davis has worked at three universities: The University of British Columbia, York University and The University of Alberta. Clarke et al. were from the University of British Columbia, and Margaret Sinclair was from York. So, two-thirds of this very small number of studies was written by what appears to be a very tightly interconnected group of researchers. An understanding of complex adaptive systems makes one respect the power of networking, so it is easy to see how this situation may be beneficial to the field, particularly in its infancy. On the other hand, an increased number of researchers with more varied backgrounds may produce openness in the system that would keep it in the zone, far from equilibrium, where creativity is optimized.

*More Description, Please*

Reviewing the included studies side by side does not imply that they are of equal merit. In fact, though the articles all came from peer-reviewed journals, the extent to
which they include the kind of thick description (Geertz, 1973) and rigorous
methodology that are the hallmarks of good qualitative work (Miles & Huberman, 1994)
vary widely.

In general, there is a noticeable lack of description of empirical methods in many
of the articles in this review. Often, methodology is well covered, including an
explanation of how complexity theory suggests a certain approach, but details about what
researchers actually did in the field are frequently missing. Particularly absent was any
detailed description of the analyses that may have been conducted on these studies. There
was not a single article in this review that shared any kind of a coding system or other
description of a systematic method of analysis.

Though their theoretical work was very persuasive, and their work with teachers
and pre-professionals appears to have been very effective, Davis and Sumara’s work has,
at times, epitomized this problem. Their earlier work (Davis & Sumara, 2001; Sumara &
Davis, 1997) was mostly dedicated to very insightful contributions to the theory of
complex adaptive systems, with the empirical portion reading as if it were there only to
provide convenient examples. In fact, the descriptions of the samples for each of these
studies were so imprecise that it was impossible to tell whether or not both articles
referred to the same elementary school faculty. In their defense, their later work provided
more description of their empirical observations, but still with no comment on data
analysis. Clarke’s research team (Clarke & Collins, 2007; Clarke, Erickson, Collins, &
Phelan, 2005) provided much more thick descriptions of their participants, making one
feel almost transported into the situations they were describing. The level of description
that they provided of Nadine’s kindergarten class provides an excellent example of the kind of rich description that would be desirable in all complexity research. Once again, however, there was no description of their methods of analysis.

Equally important as providing rich descriptions is the need to inform readers of the methods used to conduct research. Regardless of the restraints inherent in the page limits of journals and of other challenges that might discourage the inclusion of methods sections in manuscripts, it is important to share with readers how a researcher has gone about analyzing data. Otherwise, authors open themselves up to the accusation that they are simply providing isolated vignettes that support their theories, while systematically ignoring everything else.
CHAPTER THREE – METHODOLOGY AND METHODS

Research through the Lens of Complexity Theory

If, as complexity theory suggests, learning is (or at least can be) an emergent property of a complex adaptive system, and if research itself is a form of learning (Rossman & Rallis, 2003), then one might reasonably hope that individual studies and, indeed, the entire body of data in the empirical research reviewed above would have the characteristics of complex adaptive systems, so that new knowledge may emerge from the networking of the constituent thoughts. Though the field clearly embraces the nonlinearity of complex adaptive systems, it is possible that it is too tightly bound, and less than optimally networked.

Nonlinearity and the Qualitative-Quantitative Debate

Certainly, the recognition of nonlinearity endemic to complexity theory demands a healthy skepticism about entirely quantitative studies of learning. Such research strives to be “scientific,” but the science that is lionized by quantitative researchers values the isolation of single variables. This is not generally helpful when studying the complexity of social systems. One of the great mistakes that has caused humankind to have difficulty understanding complex systems is our desire to “round off.” We take complex situations and round the relatively insignificant parts to zero so that we can make manageable approximations of natural phenomena. For example, when one throws a ball, an excellent calculation of where it is going to go can be derived by simply examining the
relationships between the force that is throwing the projectile, gravity and friction (which, in some cases, can even be rounded out). Of course, there are many other forces acting on the ball. For example, countless molecules will each bump into it, attempting to move it in an infinite number of random directions. Because the ball is so large and the individual molecules are so small, however, the effect of the molecules does not need to be included in the calculations. This kind of approximation is found throughout classical mathematics and science and can reasonably be used to examine non-complex systems. If instead of a ball, however, what was being thrown was a piece of dust, close examination would reveal that the force of the molecules is so great relative to the size of the dust particle that it caused the dust to move in seemingly random, unpredictable directions. When forces are more equal, rounding off ceases to work. This metaphor of throwing a baseball as contrasted with throwing a piece of dust can be applied to the learning process. Too many variables are more or less equally at play in any learning community to embrace the enthusiastically reductionistic, positivist structure of a solely quantitative analysis (Cziko, 1989; Davis & Sumara, 2005). Indeed the very concept of analysis by dissection is antithetical to complexity thinking. Trying to understand emergence in the classroom environment strictly by isolating individual students or by parsing out single influences on their understanding is like trying to study the behavior of a frog by dissecting it. In both cases, the very things that complexivists are interested in studying are killed.

Complexity theory recognizes that the forces acting on students, classes, schools, school systems and societies are also too equal to be treated with such linear modeling.

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6 I learned this analogy in conversation with Coleen O’Connell, the director of the Ecological Teaching and Learning Program of Lesley University’s Audubon Expedition Institute.
Yet, as evident in the current No Child Left Behind mindset, some persist in believing that good test scores will indicate good learning, which will inevitably be produced by good teaching. Too often, policy makers assume that as teaching improves, learning will improve in direct proportion, as will test scores. All of this is based on the ludicrous assumption either that the only factors at work in the classroom are the quality of the teacher and the presence of the student, or that all other influences (living conditions, nutrition, family background, previous schooling, learning in a second language, and countless others) are so insignificant that they can be “rounded off.” Perhaps the best way that a researcher of complex phenomena can avoid this narrow mindset is to adopt a more ecological approach.

Though other complexity theorists may be purists in their separation of qualitative from qualitative, not all quantitative data are useless, even to studies of emergent learning. Though solely quantitative, highly reductionist methods of investigating complex adaptive systems are unlikely to be helpful, it is easy to see how incorporation of statistical data may enhance a researcher’s understanding of the system. Census data, for example, could be used, in coordination with other sources, to enhance one’s understanding of the social system in which the class is nested.

Too Well-Bounded and Intimately Networked?

As described in chapter two, it is possible that the current research community is so intimate that it may not yet reside in that zone at the edge of chaos where emergent learning may be optimized. In addition to the small number of closely associated
researchers, another issue is a relative lack of methodological variety. If diversity among agents is as important as complexity theory implies, then it would make sense that a rich variety of research methods would enhance the overall body of knowledge on complexity theory in the classroom. It may be, however, that the field is now operating under a strange attractor that is too narrowly defined. As explained above, it seems logical that sociological complexity researchers would be bound by a common commitment to qualitative methods. As things currently stand, however, ten of the twelve studies reviewed above involve only one of the possible qualitative approaches: action research (Stringer, 1999). Persuasive arguments have been made that action research and complexity theory are particularly well suited to each other (Phelps, 2005; Phelps & Hase, 2002; Sumara & Davis, 1997). Certainly, action research acknowledges the need of researchers to be “mindful participants” (Davis & Sumara, 2001) and is one way of maximizing one’s attention to praxis, but these arguments do not exclude other qualitative methods as possible rich sources of knowledge. Though action research can take many forms, there is reason to believe that using an even broader spectrum of research methods might provide richer data.

Of even greater concern than the fact that so many of these researchers situate themselves under the very broad umbrella of “action research” is their common use of the emic perspective. Though there is certainly a place in the research community for this lens, there is currently a lack of balance between the emic and etic stances. This creates a situation in which researchers are open to the criticism that they have designed classroom

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7 Most mention action research explicitly but, even among those who do not, certainly all ten fit the image of a practitioner reflecting on his or her own practice as described in Stringer.
situations with complexity theory in mind, executed those designs themselves, and then conveniently found that their theories fit. If an increased number of studies took an etic stance, they might actually create a situation where etic and emic studies were mutually reinforcing, supporting each others’ results. The study described below was designed, in part, to contribute to a methodological expansion in complexity theory research with the hope that this increased diversity may move the field slightly more toward the edge of chaos.

General Research Theory

Among the strengths of qualitative research is its acknowledgement that there is no such thing as absolute objectivity. Each of us enters a research site with a wealth of experiences and opinions that color our perceptions. Given that realization, it is always best to make these ‘biases’ explicit (Miles & Huberman, 1994). As such, rather than use grounded theory, classroom data in this study were collected and analyzed with complexity theory in mind. This is not to say that it was a hypothesis test in the quantitative sense, but rather an attempt to be explicit about the desire to apply the complexity theory lens to the classes under study. This was accomplished by a recursive process in which observations, interviews and artifacts were compared to *a priori* codes while at the same time, an attempt to find new (perhaps even contradictory) categories was made.

This investigation was designed to be what Robert Stake (2000) called a “collective case study.” Stake described a collective case study as the use of several cases
to provide insight into an issue. Unlike in an intrinsic case study, where interesting aspects of the cases themselves are the primary subject of the inquiry, cases in a collective study are chosen to facilitate an understanding of something else – in this case, a theory of learning.

Triangulation

There has been a great deal of discussion about what measures might be taken to ensure the validity of qualitative research (i.e., Creswell & Miller, 2000; Lather, 1993; Lincoln & Guba, 1983; Miles & Huberman, 1994; Maxwell, 1992). Though researchers use different names to describe their visions of rigorous qualitative studies, what they are all trying to achieve is some level of what Lincoln and Guba (1983) called “trustworthiness.” Ultimately, all researchers must answer the question “[W]hy should we believe it” (Bosk, quoted in Maxwell, 1992, p. 279)? This does not of course mean that qualitative researchers must make anyone believe that they have found some objective and unalterable truth as if they were defending the claim that a new element had been synthesized, or a new star had been discovered. Rather, given the constructed nature of reality in the social sciences, methods aimed at bolstering validity are intended to ensure that “the researcher sees what he or she thinks he or she sees” (Kirk & Miller, 1985, p. 21). Toward this end, this study incorporated a number of checks designed to provide richer data, and to check the researcher’s perceptions. These were: prolonged, persistent observation; trustworthiness; member checks; researcher reflexivity; and rich, thick descriptions.
**Prolonged, Persistent Observation**

Like in most secondary schools, classroom groupings at Metropolitan Catholic only last for only one academic year. In an attempt to provide prolonged observation, these classes were observed periodically from November to June. This prolonged engagement should allow participants to have enough time to become more comfortable with the researcher, while at the same time, providing an opportunity to reduce distortions in researcher perceptions by placing each observation in a larger context (Lincoln & Guba, 1985). Beginning in late November and extending to late May, repeated observations over this relatively long period provided the element of persistence. This complemented the prolonged study period in that while “prolonged engagement provides scope, persistent observation provides depth” (Lincoln & Guba, p. 304). These observations are described in more detail in the methods section below.

**Trustworthiness**

Triangulation (Denzin, 1978), or structural corroboration (Eisner, 1979), can be described as “onslaught of a series of imperfect measures” (Webb, et al., quoted by Miles & Huberman, 1994, p. 267) designed to provide a variety of perspectives on a given case. This study involved triangulation among observations, interviews, the examination of artifacts, and the multiple perspectives provided by studying three different groups. Though some have suggested that triangulation is intended to discover an elegant “convergence upon the truth about some social phenomenon” (Mathison, 1988, p. 14), Sandra Mathison (1988) recognized that, often, triangulation may also produce
inconsistency and even contradiction. Clearly, triangulation in qualitative studies produces an intersection of multiple constructions, which one might not expect to be consistent with each other. This may be particularly true in research on complex systems, where the individual agents may not even recognize that they are members of a complex adaptive system, yet they together cause their group to behave as such. This inconsistency is not a problem, however, because “The [true] value of triangulation is not as a technological solution to a data collection and analysis problem, it is a technique which provides more and better evidence from which researchers can construct meaningful propositions about the real world” (Mathison, 1988, p. 15).

**Member Checks**

In addition to providing other kinds of triangulation, the interviews in this study were intended to provide an element of member checking. Though, for reasons described above, Creswell and Miller’s (2000) assertion that “The qualitative paradigm assumes that reality. . . is what participants perceive it to be” (p. 125) goes too far, it is nonetheless vital that researchers represent the participants’ perspectives as accurately as possible before beginning to make analyses based on those data, trying to ensure what Maxwell (1992) called “interpretive validity.” Toward this end, much of the interview protocol in this study focused on checking in with participants to see how they perceived incidents that happened in the classroom while the researcher was observing. In addition, full copies of a draft of this dissertation were provided to each of the participating teachers in which their words and some descriptions of their classes were highlighted. They were
then invited to comment and/or make corrections. After minor corrections such as replacing the phrase “music teachers” with “band directors” in the description of one participant’s education, they found the depictions in this work acceptable.

Researcher Reflexivity

Clearly, I make no claim that I am entering this study as a clean state, devoid of opinions and prepared to engage in a purely ground-up generation of new theory. In addition, I am a practitioner in the same school at which I will be conducting research, so I have some preconceived notions about some of the participants (particularly the teachers, who have been my colleagues for some time), and about the school itself. It is important not only that I be up-front with the existence of these perspectives, and report on them in my final dissertation (Creswell & Miller, 2000), but that I constantly attend to how they are shaping my perspective on the cases under study. Though I do not claim that I can be so disciplined as to be an unbiased observer (or that it would be desirable to be so), I can use triangulation, member checks, and a determination to supplant my current perceptions of participants and their environments with new opinions derived by observations made over an extended period of time. I must also be open to the idea that the classes I have observed were not complex adaptive systems at all, and be disciplined about not trying to squeeze observations inappropriately into the definition that I have proposed.
Rich, Thick Descriptions

As asserted in the critique of the current research on complexity theory in the classroom above, the most useful data that can be reported in any account of a potential complex adaptive system come in the form of thick, rich descriptions of the case under study. Placing the words “rich” and “thick” side by side, does not imply that they communicate the same thing. Natural scientists are well familiar with the concept of rich description, recording detailed and voluminous observations with an eye toward being able to use these details in a later analysis. Robert Hooke’s detailed drawings of cork cells are a good example. They contain such fine detail that a modern biologist can look at Hooke’s drawings and identify structures within the cell that had not yet been identified when the drawings were made. Sociological research too benefits from rich description, allowing readers to know enough details about a social situation to evaluate the claims of an author, or to make their own conclusions.

Perhaps even more important, however, is thick description (Geertz, 1973). Rich description alone is rather sanitized, perhaps reporting, for example, that a student walked across the cafeteria and sat down at a given table. Sociology recognizes, however, that “social actions are comments on more than themselves. . .Small facts speak to large issues . . . because they are made to” (Geertz, 1973, p. 23). Thick description of the student walking across the room might include the fact that the student, a sophomore, was moving across the room as a kind of protest against the seniors’ monopoly on window-side seats at lunch. Just as there is a difference between an involuntary eye contraction and a wink (Geertz, 1973), there is a difference between accidentally walking to the
“wrong” table at lunch and doing it as a statement. Thick descriptions communicate the fullness of the meanings of observations by including descriptions of the social messages that simple acts communicate and fitting them together within their social system.

Data Collection Methods

Sampling

Toward the end of examining classroom situations through the lens of complexity theory, a purposive sample (Fraenkel, & Wallen, 2003) was recruited, consisting of three high school classes, with the purpose being to obtain a sample that manifested the presumed continuum of complex characteristics, from the very complex, to the mostly linear. They were selected based on teachers’ self-described pedagogical philosophies. The director of the jazz-rock ensemble ran his activities very much like a professional jazz band, with great freedom and input afforded to each of the musicians. The English teacher was a self-described proponent of constructivism well known in the school community for her innovative group work, and the math teacher self-identified as a very traditional transmitter of information. The Jazz and English teacher were selected based on the researcher’s extensive prior contact with them and frequent discussions of educational philosophy over the course of many years working together. The math teacher responded to an email invitation intended to recruit a teacher who agreed with the following statement:
I believe that my primary role in the classroom is to give the gift of knowledge to my students. As an expert in my field, I take information that I have been given by society and transmit it to the next generation. As such, my primary role is to be the giver of knowledge, and my students are primarily recipients. This means that most of the communication in class should be from me to the students, with students asking questions about the information that I am explaining to them. The knowledge in my class is not derived primarily from student interpretation. It has been passed down through the generations, or from a contemporary expert source.

These classroom environments were chosen in an attempt to determine whether there was variation, perhaps even a continuum, in the way that complexity manifested itself in different types of classroom environments. This kind of variation is implied when researchers such as Davis and Simmt (2006) and Sinclair (2004) asserted that it was possible to generate a list of “necessary but insufficient” criteria for complex adaptive systems to innovate. These kinds of criteria suggested that there was some variation or continuum in the extent to which classroom groups would manifest the various characteristics of complex adaptive systems.

Observations – The Primary Mode of Data Collection

Emergent learning of a complex adaptive system, by definition, occurs at the class level. Because the unique contribution of complexity theory (when compared to constructivism or social learning theory) is that an entire group can be viewed as a learner, it is the entire classes and/or groups that must be observed. As such, the primary
mode of data collection for this study was to observe each of the classes described above as they went about their normal process of learning. In this ethnographic spirit, observations were made on all observable aspects of classroom life. Within this comprehensive view, complexity theory was used as a lens, attempting to detect examples of networking, nonlinearity, boundedness and emergence, as well as rooting out any evidence that may contradict the preconceptions of complexity theorists.

The role of the researcher, in as much as possible, has been as a passive observer in the class. As elucidated above, much of the empirical research available on complexity as manifest in the classroom has been conducted by the designers of the programs they were studying, so, to provide a variety of perspectives, this study was designed to ensure a measure of separation between the researcher and group processes that can not be ensured when the researcher is the curriculum designer and/or teacher of the group under study. Of course, as the response of Nadine’s kindergarteners to Tony Clarke’s clothing illustrates (Clarke & Collins, 2007), complexivists recognize that even a small perturbation in a system can set off a kind of butterfly effect, producing significant changes, so one must recognize that the presence of a researcher may have affected the group in some way, to some extent. This acknowledgement does not mean, however, that there is not a continuum in the involvement that a researcher can have in the daily functioning of the complex adaptive system under study. There was a conscious effort made in this study to remain strictly in the somewhat removed role of an observer, remaining silent during observations, not participating in lesson planning, and mostly concentrating on remaining as unnoticed as possible.
At least eight observations were made of each of these three classes, spread out between November 28, 2007 and May 28, 2008. The total number of observations was 26. Observations of different classes were alternated throughout the year, so that one could record progress in each class over the course of the entire time span. Though these observations were usually evenly spaced, some opportunities were taken to make extra observations when interesting moments arose. For example, one Friday afternoon observation of the Jazz Rock Ensemble manifested a number of interesting features. It happened on that day, the usual teacher and some of the members of the ensemble were not present. In an effort to see how (or if) the group would respond when reconstituted as a full ensemble with the usual director, another observation was made the following Monday. Another observation was made to see the Jazz Rock Ensemble as they performed in front of an audience as opposed to the usual practice environment.

Each observation lasted for at least one hour. The schedule of this school was dominated by 45 minute periods, but classes did rotate through one period of the day that lasted for 65 minutes. Most observations of the math and English classes were made when they were meeting during that period. The Jazz Rock Ensemble practiced before and after school, with each observed session lasting about 90 minutes. All classes were video recorded with the data stored on DVDs. These DVDs served two purposes: to aid in guided recall during interviews and, supplementing observation notes, to preserve data for analysis, most of which was conducted in the summer of 2008. These recordings were wide angle shots of nearly all students in the classroom taken from a camera mounted on a tripod in a corner of the room. Occasionally, with a group’s permission, the camera was
focused on a sub-group of four to eight students. As per the attached consent forms (Appendix C), these DVDs will not be displayed publicly and will be destroyed five years after this dissertation has been successfully defended.

Naturally, in order to get as ecological a perspective as possible on as many of the influences on the classroom environments as could be observed, it was important to observe the school and its community carefully as well. Fortunately, the researcher was a veteran full time teacher at this school at the time of the study, fully embedded in the life of the community and constantly observing this environment.

**Interviews**

As complements to these observations, four members of each class were interviewed. These were semi-structured conversations about the nature of learning (both in the observed class and elsewhere), the function of group work in various classes, and general insights into the class being observed as well as the school as a whole. In addition to gathering such general information, participants were asked about various “critical incidents” (Flanagan, 1954) of which they had knowledge. The DVDs of class observations were used as a tool for guided recall, and participants commented on what they were seeing on the recordings. This provided an especially powerful method of triangulating data, since the DVDs stimulated participants to comment on specific aspects of classes that they, by their own account, would not have otherwise recalled. Comparing researcher observations with the commentary of various members of the group reinforced
much of what the researcher saw in the class, and sometimes provided unexpected perspectives on various incidents.

A form of theoretical sampling (Charmaz, 2000) was used, where participants were chosen for their potential to provide rich data, either because they were generally engaged and articulate or because they played a particularly interesting role in the class (Seidler, 1974). Naturally, teachers had a unique perspective on what was happening in the classroom, so each teacher was interviewed. In addition, three students from each class were chosen based on their unique role in a particular class incident, for their articulateness or, in one case, for his simple willingness to participate.

Generally, participants were very easy to recruit, with musicians and English students responding enthusiastically to the chance to talk about their classes. The recruiting experience was very different with the math class, however. Two students agreed relatively quickly, though getting them to return the forms and scheduling their interviews proved difficult. Getting a third student to participate was very difficult. At one point, four students had been given consent forms and verbally agreed to be the last one to participate, but kept failing to bring their forms back. In a final attempt to obtain the proposed sample, sealed envelopes were prepared containing recruitment letters and assent/consent forms addressed to each member of the class. These envelopes were placed in the packet containing the students’ final exam in geometry and the proctor was asked to distribute them to students when they had finished their tests. The proctor was unaware of the contents of the envelopes. Finally, one student came forward and was interviewed between final exams two days later.
In the end, four participants were interviewed per class, for a total of twelve over the course of the entire study. Teachers and some students were also interviewed informally on a regular basis as a member check, to keep them invested in the research process, and simply to coordinate the logistics of the study, such as when it would be best to observe the classes. In the cases of the English teacher and the ensemble director, these informal discussions were frequent and very informative. At the end of each observation, the English teacher would walk towards the next class with the researcher, with both sharing how they had perceived the day’s activities. The ensemble director gave many valuable insights into the nature of jazz, the workings of the group and other aspects of the study at various times throughout the day (for example, at lunch). Though a number of helpful side conversations were had with the math teacher, they were less frequent, perhaps because the researcher did not have as strong a pre-existing rapport with him as with the other two teacher-participants. Ultimately, despite the differences inherent in various personalities and an inevitable variance in eagerness to participate, all participants were observed and interviewed using the same protocols and therefore, their individual uniqueness only added to the diversity of the data collected.

Artifacts

As another source for data triangulation, any documents used in class during observations were gathered. These included sheet music, handouts, quizzes and tests, and other material used during learning sessions. Some student work was also obtained. In addition, copies of the major documents that defined the school community were
gathered, including the student handbook, faculty handbook, mission statements, materials advertising the school to prospective students, the alumni magazine, the school web site, department curriculum documents and other sources. (A summary of all data collection methods is included as Table 1).

Table 1.

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Participants</th>
<th>Frequency</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>All students in each of three classes. One group of nine students, one of 21 and one of 25.</td>
<td>About once every other scheduling cycle of seven school days.</td>
<td>Eight one hour observations per class plus additional as needed. Twenty-six total.</td>
</tr>
<tr>
<td>Interviews</td>
<td>Three students and one teacher from each class.</td>
<td>One audio-recorded interview per key informant, plus informal discussions with teachers and students.</td>
<td>Twelve interviews plus more informal discussions.</td>
</tr>
<tr>
<td>Artifacts</td>
<td>All of Metropolitan Catholic High School and its surrounding community.</td>
<td>As materials became available.</td>
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</tr>
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</table>

The layout of this table was adapted from Jackson (2004).

Data Analysis

As alluded to earlier in this chapter, the point of this study was not to test complexity theory as if it were a quantitative hypothesis. Rather, a modification of the traditional inductive approach of qualitative research was used. According to Frederick Erickson (1986), this approach can actually be seen as occurring in two distinct phases. First, one “generate[s] assertions, largely through induction. This is done by searching the
data corpus” (p. 146). Though the data Erickson referred to here were individual researcher notes, interview transcripts and other sources, the initial assertions of this study have been generated by examining the data corpus made available by the broader empirical research community in classroom complexity as reviewed in chapters one and two. Now, after collecting data unique to this study, analysis continued with Erickson’s second phase of induction, by “reviewing [data that were collected] repeatedly to test the validity of the assertions that were generated, seeking disconfirming evidence as well as confirming evidence” (p. 146). This analysis took the form of constant comparison (Glaser, 1965) of codes that were generated by reviewing field notes and DVDs, as well as transcribed audio recordings of interviews. Coding was conducted with a goal of recursively examining data in a way that sometimes consolidated and sometimes complexified data for the dual purpose of seeing patterns and leading to new questions or adding depth to analysis as described by Coffey and Atkinson (1996). These codes were compared with the characteristics of complex adaptive systems proposed in chapter one and with the research questions that were the focus of this study.

A priori codes for a preliminary examination of the data were taken from the elements of complex adaptive systems highlighted earlier in this volume (see Table 2). In fact, the initial codes read like an outline of

<table>
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<tr>
<th>Well Networked</th>
<th>Agency</th>
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<tr>
<td></td>
<td>Short-Range Relationships</td>
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<tr>
<td></td>
<td>Nested / Fractal Networking</td>
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<td>Nonlinear</td>
<td>Systems far from equilibrium</td>
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<td></td>
<td>Feedback</td>
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<td></td>
<td>The Butterfly Effect</td>
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<tr>
<td>Bounded</td>
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</tr>
<tr>
<td>Synergistic</td>
<td>Emergent Learning</td>
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</tbody>
</table>
the “Towards a definition of complexity theory” section of chapter one. As this initial
coding pass was being performed, other codes that did not immediately appear to fit any
of the *a priori* codes were devised as in a traditional grounded theory approach. For
example, some participants made points about the decisions that must be made in a
curriculum between breadth and depth, so that became a code. Making space in the
conversation (verbal or musical) was another theme that arose and appeared to merit its
own code. Other coded themes were: constructed vs. absolute knowledge, change vs.
sameness, the nature of leadership, the nature of jazz, perturbations in the system, agent
background and class characteristics. Subsequent passes revealed that some of these
codes were descriptors of *a priori* concepts. For example, “perturbations in the system”
became a descriptor within the “butterfly effect” category. Some grounded codes
contributed to multiple *a priori* codes, as was the case with “the nature of jazz,” and
others called for their own new category, entitled “external influences.” A full accounting
of all categories as arranged in the final analysis can be found below. First, however, with
an eye to providing context, an introduction to the participating groups and to their
environments is in order.
CHAPTER FOUR – THE THREE CLASSES AND THE ENVIRONMENTS IN WHICH THEY WERE NESTED

Metropolitan Catholic High School

Metropolitan Catholic High School is a large (1500+ student) Roman Catholic secondary school for young men on the East Coast of the United States. Founded near the middle of the nineteenth century by the Society of Jesus (more commonly known as the Jesuits), it is now independently owned by a board of trustees. Still, it remains very committed to its uniquely Jesuit identity, with many priests serving on the board, and with the leader of the resident community of priests and brothers being an integral part of the administration of the school. Though only a few priests now work there, religion is an important part of the curriculum. The entire school gathers for liturgies and teachers across all disciplines are trained in the history, traditions, and unique spirituality of the Society. To ensure that this charism remains a part of school life, there is a Vice Principal for Ignatian Mission and Identity. The word “Ignatian” refers to Saint Ignatius of Loyola – the founder of the Society of Jesus.

From its connection with other Jesuit secondary schools, primarily through the Jesuit Secondary Education Association (JSEA), M.C. High shares a common mission with other Jesuit schools across the country. It is called “The Graduate at Graduation” and is the central guiding document for the life of the school. Each institution across the country adds its own flavor to the document, but they are substantively the same. The
M.C. High student handbook, faculty handbook and online information describe the “Grad at Grad” this way:

Each student has been provided with and, hopefully, generously responded to, the challenge to become a young man who is:

**Open to Growth**: that is, he has matured as a person – emotionally, intellectually, physically, socially, religiously – to a level that reflects intentional responsibility for his growth; and he is beginning to reach out, seeking opportunities to stretch his mind, imagination, feelings, and religious consciousness.

**Intellectually Competent**: that is, he has directed much of his energy toward the pursuit of knowledge; he not only exhibits competency in those academic skills needed for further education, but has also developed skills and understanding that go beyond the requirements for college entrance; and he appreciates the need for intellectual integrity and self-motivation in his quest for justice and truth.

**Religious**: that is, he has a basic knowledge of the major doctrines and practices of the Roman Catholic Church; and he has examined his beliefs with a view to establishing an active relationship with a religious tradition and community.

**Loving**: that is, he is well on the way to establishing his identity; he is moving beyond self-interest and self-centeredness in his relationships with others; and he is beginning to disclose himself while accepting the mystery of other persons and cherishing them.

**Committed to Doing Justice**: that is, he has gained specific knowledge of the many needs of local and wider communities; he is preparing for the day when he
will take a place in these communities as a competent, responsible, and concerned member; and he has begun to acquire the skills and motivation necessary to live as a person for others.

Evidence that this document is central to school life include the fact that M.C. High began offering community service options in the 1970s and made them mandatory in the early 1980s. Reflection groups that are held as a part of this program focus on how the Grad at Grad is applied in the “real world” during service experience. The document is at the center of the religious retreat program, and the senior paper, which is required for graduation independently of the students’ other grades, is about the Graduate at Graduation. Curriculum mapping is a relatively new part of school life, but all curriculum coordinators are now being asked to insert references to the Grad at Grad into their maps in much the same way that a public school department would have to account for the state standards.

Though it is located in the city, M.C. High draws students from a number of different communities. Some walk from the nearby inner-city neighborhood (about 30% of the student body come from various nearby urban areas), others take the subway or commuter train, while some commute for as many as 50 miles each way. Tuition for the school year during which this study was conducted was $12,600 plus the cost of books, transportation and other expenses. In order to encourage economic diversity and, to a lesser extent, to attract talented students, the school distributed nearly three million dollars in financial aid and scholarships each year to more than one third of the student
body. This number is growing rapidly, largely due to the generosity of the alumni and other supporters.

In terms of traditional academics, M.C. High is a definitively college preparatory institution. Admission is very competitive and 99% of students generally go on to four year colleges. The remaining few choose the military, community college or a postgraduate year at a preparatory school. Students are required to take four years of math, English and religion, three years of a modern or classical language, two years of science and social studies as well as some sessions with the guidance department, health classes and art and/or music. Each of these meets a few times per schedule cycle. Most students take a third year of a science, since it is a common college entrance requirement. Electives are numerous and diverse, from marine biology to world literature. Twenty four AP classes are offered, and, in the year of the study, 80% of students who took these exams earned scores of at least three (out of five).

The last five years at M.C. High have seen a massive expansion and renovation of the campus, including the addition of a 65,000 square foot facility that connected the other buildings on campus, which were previously separated by a grassy quad in the collegiate style. This new building now houses the science department and other classrooms, as well as the cafeteria. The facility centers on an atrium, known as the commons, which is surrounded by student services such as the cafeteria, library, campus ministry office, student affairs office, and guidance. The main office and nurse’s suite are nearby.
The 2007-2008 school year brought the inauguration of a new division, serving the seventh and eighth grades. For most of the history of the school, certainly the last 80 or more years, this had been an institution serving grades 9-12. The new division is physically and organizationally remote from the rest of the campus, however, so its influence on high school division life has been minimal.

Like many high schools, the faculty is organized by subject-matter departments. These departments are responsible for setting course curricula, writing common mid term and final exams, and generally giving input to assist the running of the school. To that end, the department chair serves on the academic council, which is the most powerful advisory body to the principal. The chair is responsible for acting as a conduit between the council and the department. The other major advisory bodies are the Spiritual Formation Council, which advises the Vice Principal for Ignatian Mission and Identity on religious formation, and the Community Council, which advises the Vice Principal for Student Affairs on matters of dress code, discipline, social opportunities, clubs and other aspects of school life that complement the academic experience.

This description of a competitive religious college preparatory school for boys no doubt raises the question of how generalizable the results of this study will be. First, complexity theory recognizes that there are too many factors that make schools similar and different from each other to choose whether only single-sex schools can be compared, or whether only schools located in office parks are similar, or whatever. There are simply too many factors (obvious and unnoticed), interacting in nonlinear, synergistic ways, that make school environments unique. Qualitative research, and this study in
particular, are presented as kinds of documentaries of one unique school situation at a time.

That said, there are some obvious ways in which M.C. High is not unique in the educational landscape. According to the most recent U.S. Department of Education survey, Catholic schools served more than 2.5 million students in the United States – a little more than 44% of the total number of students in private schools of any kind. Nearly 623,000 of these were enrolled in grades 9-12. In addition, almost 17% of privately owned Catholic schools served only male students. (National Center for Educational Statistics, 2008). M.C. High is a member of the 48 school Jesuit Secondary Education Association, a group of genuinely like minded institutions. So, though it is not the classic American comprehensive high school that dominates the secondary education landscape in this country, M.C. High is, nonetheless, similar in many obvious ways to a large number of institutions across the country.

The Classes Under Study

Of the hundreds of different classes that meet across the school throughout the year, three were chosen for this study. The self-declared educational philosophies and teaching methods of these three teachers was the primary selection criterion, with one group (the Jazz Rock Ensemble) presumed by theorists to be fertile ground for complexity, another (the English section) chosen for its articulate, energetic teacher, and for the strongly constructivist pedagogy she preferred (rich in group work and opportunities for students to voice their opinions), and one where complexity theory
suggests not much emergent learning would occur (the geometry section), wherein the traditional teacher-centered transmission of knowledge dominated.

The following descriptions will begin by situating each class based on its place within the school environment based on documents such as the course catalog and curriculum maps. The teacher and each of the students will then be briefly introduced, followed by general impressions of what classroom life was like based on observations over the course of the school year. This structure is not intended to give primacy to the teacher or other individuals, but is intended to provide background that will inform the description of the group, which is the real unit of study in this work. The descriptions of these individuals are important in that theirs are the voices that will provide commentary about the classes, adding to the researcher perspective. For a reader to understand their commentary in context, it will be useful to know a little about who the participants were. Certainly, book-long biographies could be written of any of these participants, so I do not presume to capture everything here. Basic information about the kinds of communities participants were from, their academic and social backgrounds, as well as characteristic quotes are presented simply to give the reader some idea of the perspective from which each participant spoke. The classes will be ordered from the one originally presumed to manifest the fewest characteristics of complexity to the one that the literature suggested should display the most complex activity.
Geometry

Place in the School Environment.

Every student at M.C. High was required to take geometry, and, unless they tested out of Algebra 1 prior to their freshman year, most students took it as sophomores.

According to the course catalog:

This course uses precise language to master geometric concepts, terms and spatial relationships. Concepts include deduction, induction, perpendicular and parallel lines, congruence, similarity, right angles, triangle trigonometry, polygons, circles, constructions, areas and volumes. Knowledge and understanding of structures in mathematics and the nature of proof are the main goals.

It was a class that was very much focused on the acquisition of basic mathematical skills.

Brad Coughlin, the teacher, when asked, “Do you think that, at this level -- the freshman and sophomore level -- [math is taught] for its own purposes or for the purpose of giving them the language and tools for some other things?” replied:

I think for all students, it definitely serves first as a foundation, and then it splits.

For some students it really is just that foundation so that they can go off and they can flourish, whether it’s in future math classes or whether it’s in the sciences. For some kids, algebra II is the top of the food chain for them. They’re not going to go any further and in that sense, the skills are important for some of the evils
they’ll face – the SAT – and challenges like that that they’re going to have to face, for whatever they’re going to do.\(^8\)

He believed, however, that just the learning of these skills represented:

great mental pushups. . . . Just like any other muscle in your body, you’ve got to get that brain exercising, especially during the developmental years. And if the students are not required to do that type of mental work, that muscle just never gets developed.

Participants.

Mr. Brad Coughlin. Brad grew up and attended public school in Connecticut before going to Princeton to earn a bachelor of science in engineering in operations research. He described the degree as “[an] applied math approach to economics with a focus on operations – production, transportation networks, distribution, inventory models.” Starting off in business, he worked for a while doing business development for a charter school firm, then worked in human resources at a large bank. This HR job was so distasteful that it caused him to reevaluate his career path, and he decided to go into teaching. Though it was October, there was an urban Catholic high school that suddenly needed a math teacher, so he went to teach there. Having no formal training as a teacher, he described it as “learning on the fly,” and though he was “making mistakes and learning from them on a daily basis” he perceived that the school was in need of “new

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\(^8\) Participant quotes have been edited throughout this study. Only repetitive phrases, multiple attempts to compose the same thought, or inappropriate overuse of words such as “like” have been removed. This has been done to maintain the integrity of participant contributions while at the same time providing enhanced readability.
blood in the school that was not even close to jaded” and as a person who “wanted to be a part of [the students’] lives and learning experiences,” he provided value beyond his teaching abilities.

The salary and academic environment frustrated Brad, however, so he applied for a newly created position in development (fund raising, facilities planning, etc). Though he says he had the support of the principal, the board eventually went with someone else. Left looking for a better paying job, he applied and was hired to teach in the math department at M.C. High in the summer of 2004. He described the move to M.C. High as a challenging transition in that many of the lessons he had taught himself at his previous school did not work in this new environment. There was a department-wide curriculum to attend to and the students learned much faster. After about one and a half years, he felt he had become used to the number of topics he was expected to cover in the course of a given year.

In addition to learning “on the fly,” Brad’s preparation as a teacher included a trip back to Connecticut that he made to consult with his own high school teachers. He had remained sporadically in touch with one of them, and he set up a meeting with them specifically to seek their advice. He did not attend a school of education and was not certified. It should be mentioned that private schools are not required to seek out certified teachers.

At Metropolitan Catholic, tenure was awarded if one was offered a contract for a fifth year. Brad was reportedly not offered tenure. Though he was interviewed two months after he would have known this, he failed to mention it in his interview. In fact, I
did not know that he was leaving the school until he was called up to receive a parting gift at the end of the year faculty meeting. Subsequently, I made many calls to Brad’s residence, always getting his voice mail. Emails also went unanswered. I gave him an opportunity to continue participating in the study by reviewing drafts to be sure that he was accurately portrayed; to withdraw from the study, but still allow previously collected data to be used; or to be removed from the study completely. On one call, I made it clear that, unless he called back, I would treat the situation as if he had left the study at the end of the school year, but allowed the use of previously collected data.

Because of his failure to call or write back, and because asking too many questions about his departure would violate his confidentiality agreement, it is impossible to say with certainty what caused Brad to leave the school and the study. However, he did indicate in his interview that he had not made any progress toward a master’s degree, which was a major requirement for tenure. By far the most likely scenario was that this lack of educational progress was the major reason for his departure. This conjecture is supported by the fact that the most recent contract negotiation between the teachers’ association and the board of trustees now allows the administration to award tenure with the fifth, sixth or seventh contract. This was presented as an opportunity to give a chance to teachers who came in with bachelor’s degrees and immediately started coaching or moderating groups with such enthusiasm that they did not have time to take a sufficient number of classes. Brad was a multi-season coach, so this parallels his scenario. It is even possible that his situation was the one that prompted this change. Since Brad consented to be observed and interviewed right up until the last day of school, it is very unlikely that
the study played any part in his departure, or that he wished for any data collected to be removed from the study.

**Don Fairlane.** Don was a sophomore from a middle class suburb. He attended his local public schools before coming to M.C. High, but, without being asked, he volunteered that it was “not the greatest public school system,” claiming that “the teachers didn’t really care too much.” He found M.C. High to be a much better fit, but was not hesitant to talk about his current and past teachers. He described really liking having religion as a class, but said that he completely didn’t understand what the teacher’s notes had to do with what was being discussed in class. In a couple of cases, he described “not getting along” with some of his teachers. On further questioning, it seemed that the source of this perceived conflict was actually Don’s failure to do all of his homework. Don had a tutor for geometry who was not affiliated with the school, and self-reported grades in the “C” range, which was an improvement over Algebra I, which he “hated.”

**Guillaume Jardin.** Guillaume was in the first generation of his family to be born in the United States. His mother, with whom he lives, was born in Haiti and spoke broken English. They lived in a troubled low-income housing project, where he cited crime as a serious problem. “I’ve witnessed a lot, a lot.” He attended a charter school from grades K-8 and described having a real change of heart about schooling at about the sixth grade:
From kindergarten to straight on I wasn’t the best student. I was in trouble a lot. I guess I misbehaved a lot, and that was because I really didn’t receive as much guidance as I wish I did, but from sixth to eighth grade, I just started to change, and ended up being valedictorian.

Mr. Coughlin, who was also Guillaume’s basketball coach, was tremendously impressed by his work ethic, both in the class and on the court. Though things didn’t necessarily come easily to him, he was extraordinarily tenacious about making sure that he learned what he needed to. This was confirmed by Guillaume’s behavior in the researcher’s science class as well.

Sometimes, Guillaume felt self-conscious about being the only black person in this class, or one of few black students in his other classes:

Sometimes I don’t feel like asking a question because I feel uncomfortable because I’m the only black kid in the class, so sometimes I feel like if I ask a question, that, all of these kids already get [other students might think] “oh he’s a kid who doesn’t get it because when he was younger, I guess the education he had didn’t, provide him that answer, provide him with that, type of knowledge to understand the material. . . . Sometimes I’m worried about it; sometimes not. Sometimes I come into class, I’m like, “I don’t care what someone thinks. If I have a question, this is my life so I have to ask it.” I’ve seen it happen before, so I
kind of don’t want to be the person to have people think a certain way about our race, or whatever.\textsuperscript{9}

Both from the perspective of a researcher and a teacher, the dominant image Guillaume puts forth is one of a young man who most often has the courage to say, “If I have a question, this is my life, so I have to ask it,” a rarity among all adolescents.

\textit{Steve Millis}. Steve was the student who responded to the general request for participants included in the students’ final exams. Generally a solid B student, Steve lived in a distant suburb, giving him a commute of more than one hour each way, which involved a ride to the train station, a long train ride followed by a transfer to the subway. He was generally content with geometry class, but preferred classes in which there was more discussion. Comparing geometry with other classes, he said, “I think both Latin and math are very just systematically taught. You have to learn it. There’s not much thought you put into it. It is what it is. They’re more structured than another class would be.” About his favorite class (U.S. history), as well as religion and English, he said, “[In] those ones your opinion on certain things can vary and you can have more open discussion about a topic, which I like better, so you get more. There’s more thought you can put into it rather than just having to learn something.” Steve also liked to lead groups in geometry as well as in his other classes. He would, by his own account, actively seek the leadership role, facilitating the solving of problems or answering of questions with other students.

\textsuperscript{9} The researcher is Caucasian, so when Guillaume says “our race,” he is not speaking about himself and the researcher, but about himself and other black students or black people in general.
Description of This Geometry Section

This particular section of 21 students was composed entirely of sophomores. The pedagogy was dominated by the sequence: review homework or previous quiz, cover new material, practice in class, assign homework. Sometimes practicing in class would involve breaking into small groups, but often students would work on their own. Even when students worked in groups, it did not seem that the goal was to derive new insights, but rather to assist each other in obtaining the one and only correct answer by one of a limited number of possible routes. The students sat in five rows, facing the board. The teacher was the dominant focus in the room. Mr. Coughlin was willing to answer student questions and would often derive examples in his head which he put on the board to help answer student questions. Homework was generally assigned out of the textbook, but, particularly as the review for the final exam began, extensive use was made of handouts such as the one in Appendix E.

English

Place in the School Environment

Freshman English was also part of the core curriculum, and every freshman took the same English curriculum. Though there was until recently an “English I Advanced,” which required an advanced score on a placement test, all freshmen during the time of the study took the same introductory English course. Of English I, the course catalog said:
This foundation course will develop students’ skills in five areas: vocabulary, grammar, elements of effective oral expression, paragraph development, and critical reading skills. Students are introduced to all genres of literature, with an emphasis on Shakespearean tragedy and Homeric poetry.

Though at first glance this may read as a similarly skills-oriented course as geometry, the essential questions from the curriculum map revealed deeper goals. Interspersed among rather standard questions like, “What are the features and functions of epic poetry?” and, “What are the modes and means of paragraph development” were deeper inquiries into the human experience, such as:

- What is a hero?
- What does it mean to be a man?
- What is the role of God in our lives?
- How does this [God’s role] link to fate vs. free will?

In fact, though students had a vocabulary book from which they memorized, and they were repeatedly writing paragraphs and being graded so that their writing skills were well honed, the entire English curriculum at M.C. High seemed to be written so as to use literature to address the larger questions of humanity. The major pieces of literature examined in this course were *Julius Caesar* (Shakespeare, 1996), presented as an archetypal tragedy, and *The Odyssey* (Homer, 1998), an epic poem. In the early months of the year, individual teachers had some flexibility as to which short stories they assigned. The rest of the first semester was spent on *Julius Caesar* and the entire second semester was devoted to *The Odyssey*. 
Participants.

Ms. Gwendolyn Brown. “Ooh, you’re using pseudonyms? You have to call me Gwendolyn.” Gwendolyn was the first person who was approached about participating in this study, some nine months before it began, and she immediately agreed. She was a high energy teacher in her thirties who was chosen because she had a reputation for using well thought-out pedagogical techniques. When asked who would be the best one in his department to talk to about constructivist pedagogies, her department chair immediately said “Gwendolyn – no question.” This was just before his term ended, and Ms. Brown was elected to serve as chair – a position that she held throughout this study.

Growing up in the Washington D.C. area on the Maryland side, she attended public school before heading North to attend Boston College. Armed with degrees in English and theology, she then bartended for two years before deciding to attend graduate school at the University of Denver.

While there, she student taught at the Expeditionary Learning School, where they used a “team teaching approach, thematic units that were across the board, so when I was there, there was this theme of ‘The American Dream’ that was taught by science, Spanish, math and I taught the humanities.” This appreciation of active learning and integration seems to have stayed with her as she moved into her professional teaching experience. Enthusiastic about beginning a career in public education, Ms. Brown was preparing to attend a large job fair when Columbine shootings happened just a few miles
away. Jarred by the experience, she tried to think of what kind of schools could create environments where students would learn civility:

So my question for all of the schools was, “What do you do at your school to create community?” because I feel like that was the gaping wound that led -- not that it’s directly a result of -- but that led to an environment that let something like Columbine happen.

The only school that had a good answer to her question was an all-male Jesuit high school in Colorado. By the time she was contemplating a move back to the East Coast, she had decided that she:

really loved the traditions of the Jesuit school and I really love what it does allow you to consider in a classroom and how it does allow you to teach your students about the importance of the wholeness of their person and their role in this world.

So she applied to M.C. High and was in her seventh year there during the time of this study.

*Jim Cartman.* After being born in the city, Jim spent most of his life in the suburb in which he now lives. Contiguous to the city, this town was a mix of middle class and very wealthy neighborhoods. Jim lived in a middle class section and attended his local public schools before coming to M.C. High. He definitely preferred learning constructed knowledge, citing math as his least favorite class, because, “There’s only one answer and one answer only for everything you know? You can’t do like any ‘what ifs’ or anything, so you can’t say, ‘If something were like this.’ There’s one answer and one answer only.”
In contrast, when it came to deriving insights in English, without being asked about Jim specifically, Ms. Brown singled him out, saying, “He always intrigues me. He always brings in an idea that I had never considered in terms of connection . . . and he loves that.”

Mike Lazarino. Mike lived in a suburb on the other side of the city from Jim and switched from one subway line to another to get to and from school every day. M.C. High was only his second school, as he attended a K-8 Catholic school in his home town. Always a fan of math, because he had always excelled in it, Mike said that his favorite class changed to English because:

In my old school, we weren’t really into standing up doing something in front of the class . . . [but] we do that a lot in English class, so it’s almost like a routine thing. And, yeah, you’re more active in the class. You’re more involved.

He was the epitome of an external processor, but despite his ability to dominate a conversation was very conscious of the need for everyone to participate:

Everyone definitely has a good take on this book [of *The Odyssey*] and could all say their own opinion and then have a great idea about it. There’s a couple kids in my class where in the Socratic seminar they would have really good ideas and open up a new topic. The only thing is they don’t speak. You have to really entice them to speak. You have to, you know, “Hey, why don’t you say something?” then they’ll say it.
Tom Gerard. The son of two faculty members, Tom lived in the same middle class area of the same suburb as Jim. They did not go to school together, however, as Tom was educated in the local Catholic school. Tom liked English class for similar reasons as Mike:

Some classes we’ll just sit and we’ll take notes, and you know it will be just kind of boring . . . In Ms. Brown’s class you know what everyone’s thinking because everyone wants to contribute. Everyone wants to tell what they’re thinking. Tom was similarly willing to process externally as Mike, but was less likely to be the first one to speak, listening to the group and synthesizing before volunteering his thoughts. Still, he was enough of an external processor to wish that there were even more opportunities to speak:

You usually learn something from what they’re saying, but I always want to budge in to say, you know “this is what I feel about what you’re saying. I don’t necessarily agree with what you’re saying.” We have this rule where you’re not allowed to raise your hand, and you’re not allowed to interrupt someone. I wish you could just say, “You know what – hold on right there, I have something to add to what you’re saying.”

Description of This English Section

Ms. Brown described this group as being dominated by external thinkers, “I would say there’s probably four of them . . . who need to think things through inside. The rest of them need to say stuff out loud or it doesn’t make any sense to them.” It is worth
noting that among these external processors was M.C. High’s first visually impaired student. Though special technological tools were in place to help him see (to the very small extent he could) anything that might be written on the board and to “read” the texts, his natural tendency, independent of his disability, to be a very vocal external thinker seemed to help him fit well into this class.

The activities observed in this learning community were well tailored to the external processor. For example, students broke into groups to generate maps that communicated the story of *The Odyssey* up to the point they had read (Examples can be found in Appendix F). Another time, groups of students were tasked with creating a “Tableau Vivant” of a particular scene in *The Odyssey*. In this activity, students were asked to create a kind of still life portrait of the passage in question using their own bodies. Requirements included that everyone must be still, but still convey motion. There had to be high, medium, and low elements (in terms of height off the floor), and, though otherwise a silent exercise, one student would read a group-selected passage from the book that the Tableau sought to portray. Students displayed a tremendous amount of creativity and insight into the text and its underlying themes in both of these activities.

As much variety as was observed in this class, however, there was one dominant exercise that was most frequently used to learn about various books of *The Odyssey*. This was the Socratic seminar. In this exercise, half of the class was arranged in a circle, while the other half formed a larger circle behind them. The main task of the inner circle was to discuss a particular quandary given to the group by the teacher. The outer circle evaluated
the work of the inner circle. Half-way through the class period, the groups of students switched circles and repeated the exercise, this time considering a different quandary.

There were very specific rules and roles associated with this exercise. For example, members of the inner circle must refer to textual passages from the book to keep them on task. Students must not raise their hands, must not interrupt each other, and must not communicate with the teacher at all. They were encouraged to ask probing questions of each other, to develop “schema” (connections to their own “real world” experience) and every member must speak at least once. Members of the outside circle were given particular monitoring tasks, such as diagramming the flow of the conversation, choosing a “king of the seminar,” identifying particularly insightful questions, or monitoring the number of times each student used the word “like” in an excessive way. In the inner circle, there was also a “hot seat,” generally empty, that students from the outside circle could occupy for just a moment if they wanted to influence the conversation in the inside circle. This was an especially interesting activity to look at through the lens of complexity theory, so much more description will be available in the upcoming analysis.

*The Jazz Rock Ensemble*

*Place in the School Environment.*

Unlike English and geometry, the Jazz Rock Ensemble was not a required part of the core curriculum, or even an academic course in the traditional sense. Like all
instrumental ensembles at M.C. High it was not part of the regularly scheduled school day, but met before and after school. Optional activities like the Ensemble that met outside the school day (including athletics, thematic clubs, etc.) were referred to as “co-curricular” in order to reflect the fact that they complemented the “academic” offerings scheduled during the regular school day.

Composed of just seven musicians, it was the elite group among the instrumental ensembles. In addition to the Jazz Rock Ensemble there was a pep band / concert band, a chamber orchestra, and a jazz big band called, Jazz One. Admission to the Jazz Rock Ensemble was by audition and was based solely on the talent and commitment of the individuals. There was not, for example, a trumpet slot that needed to be filled. If there was not a trumpet player of sufficient skill, there simply wasn’t a trumpet in the ensemble.

This group was intended to provide an advanced experience of playing jazz, which is a musical genre that requires a great deal of musical knowledge and skill. When asked whether high school students could really, successfully, do the kinds of things that were required of jazz musicians, director Mark Flynn responded:

They have to be trained. It’s very interesting that first of all, yes high school students can do this. They do it; they get better and better and better at doing it, but it’s so out of their norm, and the culture that they are generally immersed in that you really have to, in some ways, pull them out of that culture and in some ways say, “Yes you’re inundated with this, but there’s something over here that’s
really going to knock your socks off if you open yourself up to look at it and kind of immerse yourself in it.

Participants

Dr. Mark Flynn, (D.Mus.). Mark grew up in New Jersey and attended Catholic school from grades K-12. Wanting to be a rock guitarist, he went to Berklee College of Music because, “It was a place you could go and be a guitar player. Most legitimate college or university music programs really didn’t even have guitar majors, believe it or not.” After Berklee, he got his masters at Fordham in special education with a concentration in emotional disturbance. His student teaching experience was in a locked-down ward at a hospital. After teaching for a while, he earned his doctorate at the New England Conservatory of Music, where his dissertation was about the evaluation of band directors using portfolios.

Originally a rock guitarist, Mark, by his own account, avoided jazz, even at Berklee, which had a rich jazz tradition and culture. Always an enthusiastic music theorist, however, Mark became interested in jazz over the years, first as a theorist, then as a listener and musician. Mark was, by the time of the study, a genuine jazz enthusiast and very well versed in it.

Mark was only the second music teacher at M.C. High. In 1984, he inherited a program that was only three or four years old and consisted of a one semester required class for freshmen and one ensemble – the concert band. By the time of this study, there
were a number of academic offerings (including AP Music Theory), the instrumental
groups described above, and a concert choir. Though he began as the only music teacher,
he now has a choir director and an assistant band director, who worked a great deal with
Jazz One and was often asked to give feedback or even substitute as director for Jazz
Rock Ensemble rehearsals.

Mark was a very intense person. When you asked him a question, he would look
you in the eye and give an answer that clearly came from carefully considered, deeply
held beliefs. This was true not only in formal interviews but even at lunch, where he
thrived on substantive conversations about theory and policy much more than the latest
baseball score or television show. One might expect such a person to be the center of
attention in a rehearsal but, in the case of the Jazz Rock Ensemble, this was not the case
at all. Reflecting on the contrast between Mark’s personality and his pedagogy, one
ensemble member said:

He’s actually more laid back and instead of showing us what we should do when
we should do it, which some people call teaching, I think he actually teaches more
of a valuable lesson by letting us learn from each other and learn what works in
certain situations.

Ezekiel Roberts. Ezekiel, a sophomore, was the youngest member of the
ensemble, but to look at him, one would think that he was the oldest. Physically larger
than his peers, he had the deep voice and dark skin tone of Barry White. He grew up in
the inner city and attended the same local Catholic school from grades K-8. Though there
were not many music offerings at his elementary school, Ezekiel began private drum lessons at the age of six with a friend of his parents, and then with some instructors from a nearby conservatory of music. At age eleven, he joined a formal program at the conservatory, which he finished at age 14, just before coming to M.C. High. In addition to being a very good musician (having been voted best musician in the competition at a recent event in which the Jazz Rock Ensemble played), Ezekiel was effusive and talkative, which was unique in this ensemble.

*Gary Sedopoulos.* Of Gary, Dr. Flynn said:

I would say Gary truly is the foundation of the band, and I could say that musically as well as socially. Gary misses no rehearsals. Gary is never late. Gary is -- he’s the guy that I would just say, you know, “You need someone who’s reliable and you can really trust, go talk to Gary.” Quiet – you could easily misunderstand the face that you’re seeing, but he’s just solid as solid can be. And that’s true musically speaking too.

Gary commuted in from an upper middle class suburb about 20 miles outside of town. He attended public school before coming to M.C. High in the ninth grade and was a senior at the time of this study. Though he studied bass since the seventh grade with a private teacher, and played in an outside band, Gary initially chose track over the band. A serious injury sidelined him, so he decided to join the music program. As such, this was only his second year in the Ensemble. Gary was very quiet, but, like Dr. Flynn, his peers recognized him as a force in the ensemble. Ezekiel, for example, said, “Gary doesn’t say
much, but he’s there when he should be. Like, he’ll make a decision if nobody else is going to make it.” Of his own role in the ensemble, Gary said:

As a bass player, I feel like I’m pretty content to sit back and make sure that everybody else can do whatever they need to do, as in I keep time and make sure that the chord changes are outlined . . . and though I’m not a front man, it’s equally important, if not more important because what you do can make everybody else sound good or bad. I mean, regardless of what they do – they could play something great, but if the bass player is completely messing up behind them, it’s going to sound horrible, especially since low tones tend to be the basis for the rest of the chord progression. So I’m kind of content being in that role . . . because that’s my personality. I don’t want to be out front, having everybody look at me all the time. I don’t feel the need to do that.

Mitch McIntyre. Originally an alto saxophone player, Mitch switched to tenor sax the year before the study at the request of Dr. Flynn, who wanted to bring another alto sax player into the Ensemble. A senior at the time of the study, Mitch had the longest tenure among the musicians in the Ensemble, having been a member since his sophomore year. He began playing the sax in the fifth grade in his town’s public school music program and it wasn’t until he joined the Jazz Rock Ensemble that he started studying with a private instructor.

Though generally a quiet personality, Mitch was very conscious about the need to contribute to discussions during practice. When the students would finish a song and Dr.
Flynn would say, “What do you think?” Mitch was almost always the first to offer a comment, generally a compliment, about someone else’s performance. When he had criticism, it was generally of the entire group. “I think we kind of lost it the second time through.” Of this part of his role in the group, Mitch said:

Yeah, I guess I try and do that. I guess since we [talk about our performances] so much, I think a lot of people feel like, “Oh we’ve probably said this a million times. The same good comments, or the same bad comments” and everyone’s just sick of saying them. I guess I try and come up with something new every time.

*Description of The 2007-2008 Jazz Rock Ensemble*

The Jazz-Rock Ensemble that was observed in this study was composed of seven members: two drummers, a pianist, a sax player, a vibes player, a guitarist and a bass player. Their yearly repertoire was set by a combination of the competition requirements that they would face throughout the year and by a collaborative process of deciding what would work best with the ensemble. In the beginning of the year, Dr. Flynn handed out ten or more scores to the group and they began playing them. As time went on, with input from all members, three numbers were chosen for use in competition: a traditional jazz piece, a more modern composition, and a ballad. They were, in order: *Au Privave* (Parker, 1951), *Bright Size Life* (Metheney, 1973) and *Chelsea Bridge* (Strayhorn, 1941). Though other songs from the original repertoire were periodically used in rehearsal to keep things interesting, the vast majority of the time during which the Ensemble was being observed was spent practicing these three songs over and over again. Late in the
year, a fourth song was added to the set. The Latin-jazz fusion piece, Spain (Corea, 1971), was prepared for performance at the spring concert.

Unlike in a Baroque orchestra or a concert band, replaying these songs so many times did not mean that these musicians were playing the same notes and rhythms all of the time. In fact, the nature of jazz ensured that different versions of the same song often sounded very different from each other. In fact, if one listened to a collection of clips of performances of the same song that were short enough, one would be unlikely to identify them all as the same song. The art of improvisation was very much a part of the learning experience in this group.

The dominant pedagogy with this band was to have students play all or part of the way through a song and then, at the end, to have Dr. Flynn simply say, “So, what did you think?” This particular year, he described this group as especially reticent. Still, building off comments made by Mitch and Ezekiel, he did encourage other students to engage in a constructive critique of their work. Once the students had had their say, Dr. Flynn and/or his assistant would provide suggestions, critiques, recommendations for alternate patterns of soloing, and a variety of other advice.

Because this group has only one person playing each instrument, students were singled out, both by each other and by Dr. Flynn, for both praise and critique, but they seemed to understand that this was the nature of being in a group like this, and that this individual critique was in fact a positive learning experience. For example, one of the few times I saw Gary speak voluntarily in the ensemble, it was to say to Mitch something to the effect of, “I have no idea where you’re going here. You have to signal your chord
changes more so we can stay together.” This was not a moment of conflict at all, but simply part of the daily workings of the ensemble.

Conclusion

As this introduction to the classes and their members illustrates, this sample represented a great deal of diversity of pedagogical styles, goals, and personalities. Having introduced the reader to these groups, the goal of the next chapter will be to revisit the properties of complex adaptive systems covered in the early chapters of this work, this time with an eye to examining the various ways different elements of complexity manifest themselves in these three classes, the extent to which each of these characteristics was important to each group, and how the diverse styles goals and personalities under study influenced this balance.
CHAPTER FIVE – COMPLEX ADAPTIVE SYSTEMS AS MANIFEST AT
METROPOLITAN CATHOLIC HIGH SCHOOL.

Before launching into an analysis of complexity theory as manifest in classrooms, it is worth mentioning that the inclusion of three classes in this study purposefully invites comparison. It is important to understand, however, that the aim of this chapter is not to comment on the overall quality of teaching and learning happening in these classrooms. Though a discussion of the benefits and drawbacks of complexity will be forthcoming in chapter six, this analysis simply seeks to compare what happens in various classrooms with what theorists have said about complex adaptive systems. It is an analysis of how well the classes fit the theory, not whether or not these three classroom environments were in any way optimal.

Since the goal of this work was to gaze upon these classrooms through the lens of complexity theory, this data analysis will be organized, much like many of the previous chapters, using the definition of complexity in classrooms proposed early in this dissertation; namely that complex adaptive systems are well-networked collectives of discrete agents that are: nonlinear, bounded and synergistic. For ease of reading, in previous chapters each of these major topics, along with descriptive subtopics, was presented in the same order as it appeared in the above definition. A careful analysis of the data however, revealed that the issues of boundedness were so important to the participants that they set the foundation for the analysis of all other aspects of complex classrooms. As such, the bounded nature of classroom complexity will be discussed first.
Boundaries

Observing strange attractor boundaries in classrooms, I have come to prefer a biological analogy to the mathematical or physics-based explanations preferred by previous theorists. The boundary of every cell in every living thing is defined by a membrane. More than simply a boundary that defines shape and size, however, this membrane is selectively permeable. An elaborate system of enzymes and phospholipids ensures that some materials are allowed to pass into the cell and some are blocked. In the same way, passage out of the cell system is also regulated. Classes are like this as well. They allow information in (school rules, select information about their subject, certain behaviors) and they keep other things out (unwanted influences, unhealthy behaviors, noise). In doing so, they define themselves in terms of their internal structure, external form and with respect to what influences make it in and out of the system.

It was very interesting to observe how important the concept of boundaries was to many of the participants in this study, and to think about the many influences that shaped those boundaries. First among these influences was the general perception of “what schools are supposed to be like.” Teachers, for example, were in charge. No matter how much they may have attempted to distribute power and intellectual work in the classroom, the fact was that the power was theirs to give away in the first place, conferred upon them by society, families, the school, and people’s concept of schooling in general. On some level, both students and teachers entered the room with this understanding. Even if he or she wanted to, no teacher could ever truly become just another member of the class. The boundary of “what schools are supposed to be like” made this impossible.
Teachers had to give grades, take attendance, keep an eye on dress code compliance, and other tasks because these actions were part of their job at the school, as defined by convention and their teacher handbook / contract.

Another boundary was the norms of the subject areas being taught, specifically as manifest in the department-generated curriculum for each course. When in English class, one was expected to talk primarily about literature and grammar. When in math, one did problems, and when in the Jazz Rock Ensemble, one played jazz. Though connections were made to life experiences and to other subjects, one could walk into any room in the school and, within a few minutes, there would be little confusion about which subject was being taught. These curricula, of course, carried with them the norms and unique perspectives of the larger academic fields writ large. Literary scholars comment on the meaning of Homeric passages, and so did the English students. Mathematicians solve problems and so did the math students. Jazz musicians confine their improvised solos mostly to previously defined chord progressions just as the students did. Interestingly, though all classes shared some internal and external forces that participated in shaping their boundaries, each class had a unique set of boundary–making forces that made them all very different.

**Geometry**

The math class was by far the most tightly bounded. The rules in this class were very much set by the teacher and designed to create a teacher-centered environment. With the exception of the odd student leaving for the bathroom or water cooler, students were
in their seats for the entire class period. Generally, the only authorized discussion was between student and teacher, and only after the student raised his hand and was acknowledged. The focus of the class was on finding the one and only answer to the given problem.

The flow of information was perceived as being from experts, through the teacher, to the students, which left little room for pedagogical diversity or student construction of knowledge. Student Don Fairlane said:

I guess [teachers are] taught all how to teach in what subject they’re teaching, so I’m guessing whoever taught them . . . so like college professors or whatever teach teachers how to teach and teach them what subject they’re going to teach, and I think they have a curriculum to follow.

Speaking of the function of geometry in students’ lives, Mr. Coughlin portrayed the teaching of math at this level as the distribution of a toolbox: “You’ve go to learn to use the tools that are in your toolbox, and then you can be an artist with those tools down the line.” This very linear structuring of the classroom experience created a space where there was little room for student construction. In the words of student Steve Millis, “It’s usually straightforward. . . . There’s no way you can really vary from the proper answer, so you can’t debate it with someone else.”

This was a classroom environment in which there was only one possible answer to each question, and the available problem-solving tools were very difficult for students at this level to derive (mathematically) on their own. As such, the need for a teacher-focused environment with little student construction was enhanced by the fact that the
teacher had exclusive access to relevant knowledge until such time as he gave it to the students. This created a tightly bound classroom environment. The dominant boundary ended up being the nature of the subject itself, as interpreted in this class.

*English*

In contrast, there was much about the knowledge valued in English class that could be easily derived by students. They were encouraged to think about “schema” or the relationship between what was being communicated in the story and experiences with which they were familiar, creating a situation where students could conceivably run with a topic for so long and so far away from the original idea that it would be possible for the class to spiral into actual unbridled disorder. Ms. Brown recognized this, saying:

They need order, because they are going to bring the chaos to the classroom\(^\text{10}\) and that’s OK. That’s good. That’s them. That’s natural, but they need to see wherein that chaos can help them grow, and when it doesn’t help them grow, they need to be told that is not a helpful use of their energy.

This knowledge that students bring a healthy kind of chaos into the room led Ms. Brown to create activities that allowed student to express themselves, but that had well defined rules about how that expression would happen. I began to think of it as a “tempest in a teapot,” not in the usual sense of being much ado about nothing, but rather that the students were allowed to engage in this tempestuous style of learning, but that it was always tightly contained within the very hard shell of the teapot.

\(^{10}\) Here, Gwendolyn is using the word “chaos” as it is used in common language, not in terms of chaos theory.
The Socratic seminars provided great examples of how this system worked. In essence, the seminar was a system, which was itself a collection of rules. Tightly organized, students were placed in circles, told under which circumstances they could speak, reminded that discussions must revolve around the text, commanded to participate, and graded on the exercise. Once the boundaries were set, however, Ms. Brown simply got the activity started and allowed it to regulate itself. She was, by her own rules, not involved. Students were not allowed to speak to her and she rarely intervened in the activity except to say that time was up. When asked about how Socratic seminar stayed on track, Mike Lazarino observed, “For the most part it will be by the internal group, because there’s usually one person that will speak up and just stop what’s going on because they’ll just realize we’re not going anywhere with this.”

As Ms. Brown observed, the students provided the tendency to move ever toward disorder, but she provided a system of containment, which could be executed by the students themselves, in which what she called chaos could remain sustainable, without spinning out of control. The primary key to the boundaries created in English class was the rules of the Socratic seminar.

Jazz Rock Ensemble

The Jazz Rock Ensemble provided a fascinating take on boundedness. The questions that were most likely to elicit the response “that’s a good question” from participants were “What is jazz?” and “With all of this emphasis on improvisation, what makes something the same song, even when you play it so differently each time?” They
were “good” questions because they were difficult to answer, not because of any lack of knowledge on the part of the participants -- quite the opposite. Defining “jazz” or giving the characteristics that make a tune a certain song are difficult to articulate in words, but rather evident to a listener. Nonetheless, these remain the two most interesting boundaries that contained the workings of the Jazz Rock Ensemble.

First, the ensemble played jazz. Despite the name, there was really nothing rock-based about it. It was designed to be a highly advanced jazz ensemble, capable of competing at the state level among other high school students, and sometimes even able to open for professional groups in clubs. So whatever jazz is, it bounded what this ensemble was like. One thing that is true about jazz is that it values improvisation. When asked, “Have you ever played the same solo twice?” all three student musicians responded with an amused or slightly defensive, “No.” As Gary Sedopolous put it:

In jazz especially, that’s one of the major differences between a style of pop music or rock or most mainstream music and something like jazz in that if a guitar player like Slash – he’s kind of renowned in the music world as a great guitarist – and he is – but every one of his solos on a song, he would play it, write it out, or learn it, memorize it, and play it the exact same time whether you see him live in concert or on a CD, whereas jazz you don’t do that and, yeah it’s discouraged to do that.

In a sense, jazz is really about the sophistication with which one approaches a song. According to Dr. Flynn, though a rocker, pop musician or blues man may play the same song as a jazz musician, in those cases:
[Y]ou’re not necessarily trying to discover something that’s totally new, and a door that’s been hidden up until now, but in jazz you are . . . and it’s all happening at very much lightning speed. The best jazz still confounds me as to how people can think creatively that fast.

Echoing the semi-permeable boundary concept, the students and teacher were passionate about maintaining the purity of jazz – controlling what influences made it into their music. As drummer Ezekiel said, “You have to learn when to incorporate things and how to incorporate them in different settings. Sometimes, they just don’t fit.” Students were careful not to try to put too much pop, gospel, rock or other musical influences that were part of their other playing into this setting. Bassist Gary was even concerned about the future of jazz being threatened by the incursion of too many influences:

I wonder how different styles of music that evolve in the culture – say rock that evolved and hip-hop that’s evolving and rap – how those get melded into how we play jazz. . . . When most kids first start to play jazz, it’s completely different from what you listen to, so you have to learn, whereas before it would be, “Oh, I love listening to jazz” if you were a kid in the ‘40s. . . . Now, I have to change my style from playing straight eighth notes to jazz eighth notes or swing eighth notes.

. . . Just the future, what’s going to happen to this kind of music?

Dr. Flynn shared Gary’s concern about outside influences getting in, but recognized that jazz concepts and skills could also move outward into other genres, and that this could be positive. As students go off to play other kinds of music, “I think all of a sudden there
will be nuance and there will be interpretation, and responsiveness that might not have been there without the jazz experience.”

Again, as in English, the nature of jazz provided a great deal of freedom with respect to what a student-musician could do in an ensemble practice. With that freedom came the possibility that songs would devolve into complete disorder and, in fact, that was the case on more than one occasion. The proverbial train would completely jump the tracks and the song would fall apart, sometimes devolving into laughter on the part of the musicians, knowing that they had lost it. Most often however, by the end of the year, even when disorder began to reign, the group was able to come back together and save the song -- an invaluable performance skill.

So, what provided the boundary to keep the improvising ensemble on the same page? In this case, it was literally a page. Most of their songs were written on a single page of sheet music, containing only a “head” (a few bars of prescribed melody and harmonies, played in unison) and a chord progression. (See Appendix G). As a point of contrast, in a classical score, every note is prescribed, there is no improvisation, and musical scores for very short songs can be many pages long. These three pieces of jazz music provided what Dr. Flynn called “a very minimal sketch,” yet these songs most often were played for four minutes each and could theoretically be played, using only this very loosely defined boundary, until one or more musicians dropped from exhaustion. In all that time, very little would need to be repeated, except for the occasional return to the head.
So the boundary of the sheet music provided guidance by communicating “everyone play whatever makes sense, given what you hear from the rest of the ensemble, but do it using a set of notes and rhythms that are compatible with this chord and this basic rhythmic feel.” This system provided extraordinary freedom, while at the same time offering the group a means to remain entirely in sync.

This constant tension between the freedom of improvisation and the boundary provided by the chord progressions on the sheet music ended up shaping the strange attractor that defined the jazz-rock ensemble experience. As with any other complex adaptive system, a few simple parameters produced increasingly complex products.

Boundary Summary

It is interesting to observe the broad variety in boundary conditions across these three classes. The first case was the tightly bound math group, in which the teacher’s exclusive possession of knowledge valued by the subject resulted in a situation where students seemed almost literally bound to their chairs with their attention focused on the board. In English strict rules provided a context within which chaotic learning could thrive, and in the Jazz Rock Ensemble, the nature of jazz both provided radical freedom to create on the fly and the perceived need to preserve the purity of the genre. At the same time, in any given moment, the defining boundary was a single sheet with a few notes scribbled on it – all that was required to define hours of music.
Well-Networked Collectives

As described in earlier chapters, there is a continuum of networking types, from the near complete absence of the network (as described in the collection of people in an elevator from Chapter One) to networking so intimate that one can lose one’s individual identity (as in a cult). The optimal condition for complex adaptive systems is somewhere in the middle – in a collective. Of course, collectives of networked individuals can themselves show great variety. Useful distinctions among three types of networks were posited by Davis and Sumara (2006). They described: centralized, decentralized / scale free, and distributed networks. (See Figure 1). In addition, three important aspects of networking have been incorporated into the definition of complex adaptive systems used in this work: short range networking, agency, and nested or fractal characteristics.

Short Range Networking

Geometry

The observed mathematics class was, for the most part, the archetype of the centralized network. At the center was the teacher, with individual lines of communication always radiating to, from or through him. It was not unlike a legislative session where one always speaks to the chairperson or through him or her to others. Very rarely did students speak to each other, and when they did, it was often in the form of unauthorized discussions about off-task topics. Occasionally, students would ask each other about solutions to problems while the teacher continued on. When students broke
into groups, the way these groups were networked showed a bit more variety. The point of group work was always to find the solutions to a set of problems. In many groups, students would sit together, but still work alone. They were not networked at all, merely located next to each other. Most often, students worked alone until one got stuck, and then he would ask the group whether anyone knew the solution. Occasionally, a student would facilitate and the entire group would contribute to answering each question. Since solving problems alone was often faster than getting contributions from many students, however, a group that chose the well-networked route would occasionally not finish in time. This set up a network in which no new ideas flowed from anyone other than the teacher, and most communication stopped at the discovery of the correct answer to the mathematics problem.

English

The Socratic seminar, as practiced by this class, was a near perfect example of distributed networking. Most rules bounding this activity were designed to provide a healthy environment in which this kind of distributed sharing of information could survive for the length of the discussion. Since students were required to speak to each other, encouraged to ask each other thought-provoking questions, and required to spread out the work of interpreting a quandary, the connections among members of the collective were frequent, varied and substantive.
One job given to members of the outside circle was to diagram the conversations of the inner ring, mostly as a measure of how balanced participation was. Since the emphasis was on measuring balance, many students would simply write the names of the students in the circle and place a number next to the names, counting how many times they participated. Interestingly, however, Jim Cartman chose a different approach. In one session, he diagramed the conversation as if he was drawing who threw a ball to whom in a circle. This diagram provided a picture not only of how many times each person participated, but who spoke to whom and how often. Interestingly, his diagram included here as Figure 3 bore a striking resemblance to Davis and Sumara’s (2006) representation of the distributed network.
(Figure 4). Just as is true of each dot on Davis and Sumara’s graphic, Jim showed each individual in the class connecting with a few other students (often more than once) and there was clearly no stable center of attention or authority figure to or from which any more information flowed than any other individual.

*Jazz Rock Ensemble*

The unique contribution of the Jazz Rock Ensemble to the discussion of short range networking was not in what type of network they produced. Like the English class, they operated as a distributed network. The interesting twist provided by the Ensemble was that this network was sustained almost entirely without verbalization. Dr. Flynn said:

> I almost think that their reticence or . . . their shyness – hesitancy to just blurt things out and speak – translated into them trying to communicate more through their sound. . . . If they were more easy with speaking, would it have made them even better? Hard to know.

Aside from the fact that this was a particularly quiet group, the fact is that, when most communication is necessary in jazz (during the actual playing of a tune), it is not possible to speak to other musicians (at least not in conventional language). Communication was constant and intimate, however. Sometimes it took the form of body language, or looks to each other, as recognized by Ezekiel the drummer:

> [An] example would be like during a song, when someone’s soloing and Gary would be holding down the form and if [the guitar or piano player] doesn’t do a change, like one of us will look at them and we’ll kind of like tilt our heads to the
side or kind of like squint at them or something signifying that a change is coming, so I’d definitely say the way we communicate with each other would probably be with looks and stuff like that.

Saxophonist Mitch McIntyre noted that there was more to the communication than nods and head tilts, however:

Well, I guess it’s a combination of both, but maybe more so. Like you play an idea – like a certain rhythmic idea – he’ll play the same rhythm on the drums in a response, and if you start getting louder, he’ll start getting louder with you and bring the whole band with you. . . . I feel like when I can really listen to the band and know what’s going on, I can think to myself, “What can I add to what’s going on right now? What can I play that will blend well with what’s going on in the band?”

In my observations, I found the vast majority of group communication was of the musical variety. It was clear that they were constantly listening to each other, and putting out musical contributions for each other to consider. Most non-verbal communication came, as Ezekiel pointed out in the quote above, when things went wrong. If something was awry about the song, one could see all of the musicians’ heads pop up and look around for the physical communication (winks, nods, instrument movements, etc.). When things were going well, however, they often played with their heads down, seemingly in their own worlds. Clearly however, they were concentrating on using their ears and instruments to communicate.
These two non-verbal communication methods (physical and musical) combined with another unique aspect of this network to expand the concept of short-range networking. In English class, if everyone spoke at once, it would be a communications disaster. In music, however, everyone was often playing at the same time, while simultaneously engaging in this millisecond-quick nonverbal communication about where they were in the form, what the appropriate volume of each instrument was, what the “feel” of the song was going to be this time through and countless other factors. In contrast to the situation in English class, the more everyone communicated at once, the more effective the network, and the better the performance.

Even though the musicians of the Jazz Rock Ensemble were not known for being especially well networked as speakers, the nature of music and their skill brought distributed networking to a new level. Liberated from the inherently linear nature of the spoken word, they created an even more intimately connected, multidimensional, nonlinear network.

*Short Range Networking Summary*

As in the case of boundary conditions, a pattern emerged in the manifestation of networking characteristics across these three classes. In mathematics, the teacher centered pedagogy – dominated by teacher-exclusive knowledge – produced interactions that resembled the spokes of a wheel, with each spoke connected intimately to the hub, but less so to each other. This image was reflected in Davis and Sumara’s (2006) drawing of centralized networking (Figure 1). In English, as manifest in the similarity between Jim’s
drawing of the Socratic seminar and Davis and Sumara’s drawing of distributed networking, students were well connected to each other and, during the activity, there was no central figure. The system was simply set up so as to self-facilitate with a reasonably even contribution of ideas from each member. The Jazz Rock Ensemble took this distribution one step further, distributing communication among seven musicians and to an audience on many levels at the same time.

**Agency**

An important factor in whether or not networking is effective is the level of autonomy of each individual in the group. As explained above, the teacher always had the most power by default, but the extent to which he or she was able and/or willing to use and distribute power was central to the nature of the network. The power to be a discrete agent in this context was not necessarily about who set the rules or commanded the attention of the group. Agency was about whether or not students’ individual, independent knowledge had a place in the classroom.

**Geometry**

The same basic force that compelled the math class to exhibit central networking reduced student agency to almost nothing in terms of intellectual contributions to the subject matter. The stated goal of this class was not so much to learn to think like a mathematician, but to have a basic “toolbox,” as Mr. Coughlin called it, either to use for surviving the standardized testing process or as a stepping stone to a level of mathematics
where more derivation was required. Frequently during class, Mr. Coughlin would use the phrase, “We’ve got to stop making things up. We’ve got to acknowledge the things that we’re told and stop making things up,” to express that students needed to use only the tools in their toolbox, in a disciplined way, rather than try to derive the answers themselves, because they were often wrong when they did so.

This goal set up a situation where the teacher had a monopoly on valuable knowledge. Much of the time, all students were empowered to do was to receive that knowledge and ask questions to refine their understanding of it. In fact, multiple students separated what they did in geometry class from the concept of “thinking.” Comparing math to other subjects, Guillaume said:

I’m able to rely on my thinking and get success, being grades in those classes, but in geometry, I have to rely on what the book says and my teacher says [or] what he writes on the board for me to have success in that class.

Also asked to compare the thought process in his other classes with that in geometry, Steve Millis echoed this separation between the learning that happened in math class and thinking:

[In English, social studies and religion] your opinion on certain things can vary and you can have more open discussion about a topic, which I like better. . . . There’s more thought you can put into it rather than just having to learn something.
These kinds of comments indicate that students viewed themselves more as passive receptors of information in math class than agents of their own learning, as they experienced in other subjects.

*English*

The interpretation of literature, particularly as viewed in this class, was significantly different than the method of learning math described above. Perhaps the most important difference was in the area of agency. When learning about *The Odyssey* and what that ancient work taught about being a man, being a hero, and other core concepts that were the aims of this class, students had wisdom to give. When one is discussing the universals of human existence, the experiences of the individuals engaging in the discussion empower them to contribute insights that might not occur to a student from another background, or a teacher from another generation. In short, student opinions mattered, and that was where they derived their agency. As Tom Gerard described the oft-used pedagogy of Socratic seminar:

> [It is] kind of a way for us to all bring our thoughts together from previous classes into one . . . and when I say, “my thoughts,” I’m contributing to the question, and I’m contributing to other people’s points and other people’s questions that they have on this topic.

Not at all a passive learner, Tom was instead describing himself as an independent thinker, someone who could “contribute” to the overall learning of the class. In this description, there was no real separation between the function of “teacher” and of
“learner.” One could be both simultaneously, simply by listening to other students, and then contributing one’s thoughts, interpretations, affirmations or disagreements. As one can see from the math students quoted above, neither of whom had Ms. Brown as an English teacher, students seemed to generally feel they had more agency in English class than in some other classes – particularly math.

_Jazz Rock Ensemble_

Musicians in the Jazz Rock Ensemble came into the group with significant experience on their instruments. In fact, it is fair to say that, with the exception of the guitar player, each was better at his instrument of choice than Dr. Flynn. On the first day of observation, both drummers were late. Not wanting to wait any longer, Mark Flynn simply sat in on drums for a rendition of Au Privave (Parker, 1951), and did a passable job. Ezekiel came in late, half-way through the second playing of the song, and took over the drums, with Dr. Flynn and Ezekiel handing off literally without missing a beat. Mark Flynn’s comment at the end was, “How does that compare to the other one prior: better drummer, but otherwise?” This acknowledgement that Ezekiel was a better drummer demonstrated that Dr. Flynn knew that, on the individual instruments, the students possessed more virtuosity than he.

This set up a situation where, in one aspect of the group experience, the students were actually more knowledgeable than the teacher. Of course, this did not take away from the fact that Dr. Flynn had far superior knowledge of jazz, the roles of each of the instruments in the ensemble, various soloing techniques, and many other aspects of music
theory and performance. The fact that students were empowered by their virtuosity, however, allowed Dr. Flynn to set up a classroom environment that mirrored the kind of atmosphere one might expect in a professional studio. Though Dr. Flynn was certainly guiding the practice – deciding which songs to work on next, occasionally stopping a song because something had gone wrong, and generally shepherding the rehearsal process – much of the discussion between songs took the tone of professionals making suggestions to one another. Flynn would ask genuine questions of students like, to Gary, “Did we decide that you were going to play in unison with the sax in this part?” to which Gary responded, “No, just during the head.” Often, students made specific, musically-sophisticated comments on each other’s work, such as, “I liked when you played the seventh in that part of the solo.”

The combination of virtuosity on individual instruments and the knowledge of jazz imparted to them by Dr. Flynn, private teachers and other sources gave this group a feel that was much more like a professional work group than the classroom atmosphere of even the English class.

Agency Summary

As conceived in this geometry classroom, students simply did not know enough about mathematics to assert much agency. In English, however, where interpretation mattered and where students’ life experience gave them valuable information to share, student agency was very strong. Taken one step further, musicians in the Jazz Rock Ensemble actually possessed some knowledge (in the form of skills) the teacher did not.
This, combined with the fact that they were in no way compelled to be there, nor would they be graded on their performance, gave them significant power to contribute their individual skills to the group.

*Nested, Fractal Nature*

Certainly, these three classes showed evidence that they were nested within and influenced by the other systems that encompassed them. Each teacher was the member of a department, which, in the cases of mathematics and English, wrote the curricula for the observed courses. Every freshman at Metropolitan Catholic read *The Odyssey* in English class, and it was not within the power of an individual teacher, or certainly of the students, to change that without going through the political process of convincing the rest of the department. Similarly, there was great pressure in geometry to cover certain topics in a certain amount of time. Dr. Flynn was the only full-time music teacher, and the ensemble was co-curricular, so it did not have a curriculum document. Their set was, however, influenced by the requirements of regional competition, and the ensemble was embedded in the school, community and other systems described in more detail below.

The departments and co-curriculars, in turn, were nested within Metropolitan Catholic High School. This influenced classroom life in many ways. First, students were selected by the admissions department based on how likely they were to be successful in a rigorous, college preparatory environment. Also, school operation was guided by the philosophy of the Roman Catholic Church in general and especially the Society of Jesus within that faith community. This meant that religion was not only an allowable topic, but
a desirable one in every classroom, social justice was an underlying theme, and academic rigor was a strong tradition. Also, many behavioral norms of the classroom were set by the school. There was, for example, was a dress code that prohibited jeans and required tucked-in, collared shirts. Ms. Brown expressed the influence of this particular school norm on her classroom when she said:

I had purple hair in high school. I don’t want to be the one that tells kids to tuck their shirts in, but I have found that that’s a way to communicate parameter. So that came into my classroom. Those kinds of parameters came into my classroom via the school’s behavioral expectations. . . . There are rules – the school’s rules: you’re in class on time, you’re in appropriate attire, you have your books with you. I feel like I use those rules to remind them of . . . order.

In addition, influencing the school, the department and the classroom were the expectations of parents or guardians, who were paying some or all of $12,600 to have their sons attend Metropolitan Catholic. They expected excellence in teaching and a good shot at getting into college for their sons. In addition, they held a wide variety of religious, behavioral, communication and other expectations.

Though it was clear that these classes were nested within various encompassing influence sources, there was constant tension between the nested nature of the relationship among classes and their surroundings with the selectively permeable boundaries that determine what will be allowed into the classroom. In many ways, the selectively permeable boundaries were powerful enough to thwart the influence of excessive self-similarity across all levels of magnification. To some extent, the teacher
and/or the class had enough agency to decide how similar they would be to their environments. For example, Ms. Brown was not a typical English teacher at this school but, because she remained within the bounds of the curriculum and her students enjoyed the class and performed well on assessments, she was permitted that difference. She mused:

I think a lot of my colleagues are very content-driven . . . I think they would be shamed by my behavior that this year, for example, we didn’t really talk about the “winnowing fan” in The Odyssey. I think some of my colleagues would be outraged about how irrelevant that was in our classroom, because content-wise, that is a super-specific and important device that Homer uses to teach us about the ways of gods and men. My kids were not interested in it. They got it, and then no curiosity. And this is the class – and I think you’ve borne enough witness to it to know. They could ask me 27 questions about, you know, what we are having for lunch today and be truly intrigued by the question. I know that students often use that kind of questioning tactic to divert the teacher from the intended course, but they truly can find curiosity in those things – had no curiosity in this particular device. And when that happens, I think the literature that we choose is rich enough to let that happen, because the kids will pick up on something somewhere else.

She selectively removed some of the content drive, while she let in some of the dress code and other influences. This exemplifies the semi-permeable boundary provided by teacher autonomy within the classroom. Ms. Brown was able to control the
environment within her classroom to which her complex adaptive system of students would respond. Though certainly not isolated from society, church or school, she was able to show a great deal of autonomy when it came to influencing this environment at this time.

That said, there were many influences that were allowed in and did create elements of self-similarity. For example, the general idea of “what schools are supposed to be like” was similar across many levels of organization, all the way out to the society as a whole. The notions of subject areas or musical genres would be similar at all levels of organization, and arguably the influence of a Western style of thinking would be found at all levels.

Though the self-similarity of these organizations was mediated by selectively permeable boundedness, perhaps a more important characteristic of fractals that could be used to describe these systems was the inability to measure the system with infinite precision. For example, one possible expression of the nested structure of the class environments can be found in Figure 5.

Figure 5 is a reasonable approximation of the nested nature of the class environment. Certainly, the class exists within a sphere of influence that includes department policy, which exists within the school, which is influenced by families, religious beliefs and societal norms. This graphic is far too simplistic to accurately represent reality, however. In the first place, it needs a third dimension through which influences can, for example, jump over church, family, school and department to reach the students in the class. For example, society may influence students to believe that the
most important thing in life is to accumulate wealth, a value that is not held by the church, school, or department and is likely not condoned by their families. The selectively permeable boundaries of the class and the individuals may, however, allow ideas from the surrounding influences to enter (or not).

More importantly, however, Figure 5 is an approximation that does not fully account for the influences on the classroom environment. For example, the Society of Jesus does not appear. Though it is an organ of the church, it occasionally experiences friction with The Vatican, which makes it a somewhat independent influence. Then, what of the interpretation of what it is to be Jesuit that was held by the individual priests in the school? What about the religious and moral ideas of the rest of the faculty? Does placing family within the sphere of influence of church accurately represent the influence of the church on families? Many were not Catholic, or even Christian. When examining complex systems, one quickly realizes that the closer one looks, the harder it is to account

![Figure 5. Nestedness](image)
for the vast number of intertwined forces that influence outcomes. The closer one looks, the more vast are the influences. This is analogous to what fractal pioneer Mandelbrot (1982) discovered when he looked at the problem of measuring the coast of Great Britain. If one simply draws an oval around the island it would have a certain length, accounting for each bay would make the measurement longer. Adding inlets causes the measure to be longer still and so on toward infinity. Similarly, the closer one looked at the influences that affected these classes, the more factors one found, the more intertwined their interactions, and the more difficult they become to measure. This had a strong influence on the nonlinearity that will be discussed in the next section.

**Networking Summary**

Once again, great variation was observed among the three groups with respect to network structure. The math class was a centralized network with virtually no agency given to individual students. English students were empowered to draw upon their daily experiences as a source of insight for literary analysis, so Ms. Brown was able to structure that class as a distributed network. The Jazz Rock Ensemble extended the idea of a distributed network as a place where one agent communicates at a time, to one where it was possible for all ensemble members to communicate on multiple non-verbal levels all at once. This was made possible by the agency provided to them most importantly by the nature of music, but also by their virtuosity, and the willingness of the teacher to allow a work-group-like atmosphere.
Certainly, each group showed evidence that it was influenced by the fact that it was nested within various other systems. There was, however, a tension between the fractal characteristic of self-similarity and the boundary condition of selective permeability. Moreover, it was clear that the closer one looked at the influences exerted by exterior networks on these classes, the more impossible it was to identify all of the factors that caused things to happen in the classrooms, just as the closer one looks at a fractal the more impossible it is to measure.

Nonlinearity

Much of the analysis above points to the fact that a simple, linear, cause and effect model of classroom life is often inaccurate. Too many factors weigh too heavily on what will occur from moment to moment to make simple “if . . . then” predictability reasonable in most situations. That said, different classes recognized this nonlinearity to different extents. Some embraced it and some tried to exert such control that it was barely detectable. This was true in all three major subsets of nonlinearity: existence far from equilibrium, the nature of feedback loops, and the butterfly effect.

*Far from Equilibrium / Operating at the Edge of Chaos*

One can not learn from an equilibrium state. Stagnation and learning are completely antithetical. In terms of learning, an equilibrium state would be one in which one knows what one knows and there is no flow of information in or out. As described in other studies reviewed in this dissertation, a sense of “cognitive dissonance” (Thompson
Emergent Learning

& Zeuli, 1999) must be maintained. This dissonance places students in a state far from equilibrium, optimally in a place “at the edge of chaos” (Lewin, 1992).

Geometry

Chaos was not a word that would ever come to mind when observing this section of geometry. The class was about order, both in terms of behavior and thinking skills. Mathematics, as manifest in this classroom, was about orderly thinking. It was not conducted at all like Doll (1989) or Davis and Simmt (2006) might suggest, but then the teaching goals were different. Students in Mr. Coughlin’s class were not taught to derive answers from scratch. They were encouraged to reach into a toolbox they had been provided and pull out the correct tool to solve a particular problem. This goal called for a much more linear vision of classroom life. In fact, the class was purposively selected to find an environment where “knowledge . . . [was] not derived primarily from student interpretation. It has been passed down through the generations, or from a contemporary expert source” (from the teacher recruitment letter).

As such, this class was structured to minimize chaotic interaction. This was ensured by the centralized network structure that dominated the pedagogy. That said, the subject itself provided cognitive dissonance. Geometry did not come naturally to many students, so the information and thought processes endemic to geometry were sufficiently foreign to generate uncertainty, so learning could occur. As Guillaume said:
I struggle for about 20 to 25 minutes of the class, like when I finally understand. As soon as I get the subject down pat, then I’m able to see, like I’m able to relate to the material. Then I’m able to get the further material.

Chaos entered the classroom with the subject matter by providing cognitive dissonance and was mitigated by the classroom environment. The goal of this class was to push through cognitive dissonance to an equilibrium state of possessed knowledge as quickly as possible. Rather than have students linger in their cognitive dissonance and derive the answers to problems that were unfamiliar to them, the goal seemed to be to remove any uncertainty as quickly as possible, learn to use the tools necessary to solve the problem, and move on.

*English*

In contrast to the pressure to push through cognitive dissonance and get to the next topic found in geometry class, English was structured to allow chaos and uncertainty to linger. Of the pace of the class, Jim said:

*We take a lot of time to go over things. Like we’re reading The Odyssey right now and . . . we’ve just been really going over it and getting out every last detail, like similes and epithets and all that kind of stuff. . . . We just really pound it out until there’s nothing left to talk about.*

In English, the state far from equilibrium at the edge of chaos was purposely fostered and extended. As explained before, the Socratic seminar and other observed activities served as ways to keep students thinking more deeply about questions raised by the readings. They were devices to provide space where a state near the edge of chaos could be
sustained and used over an extended time to produce and refine knowledge. When planning her lessons, Ms. Brown recognized that:

[R]eal learning is really messy, and school environments don’t often allow for that, so I do what I can to allow for that, but I also know . . . our role here is to find from that chaos, order.

So the English pedagogy was often designed to optimize conditions at the edge of chaos, to extend them, and to use them as a source of learning, until the conversation came to its logical end (or they ran out of time) and the order of new insight emerged from the chaos of discussion and debate.

*Jazz Rock Ensemble*

As explained previously, the point of jazz is to push the musical envelope. By virtue of this fact, a state far from equilibrium is enthusiastically embraced by jazz musicians at all skill levels. Restating what he said about the nature of jazz above, Dr. Flynn explained that, when compared to other genres, it is “just much more spontaneous, much more reaching – trying to grasp something different – something new.” So among the defining characteristics of jazz is this attempt to stay at all times away from the mundane, from anything that has been done before, from the ordinary. As a result, where in English, students “are going to bring chaos into the classroom” (Gwendolyn Brown), but then need to be tightly contained and redirected to optimize the usefulness of this chaos, in the Jazz Rock Ensemble, the struggle for Dr. Flynn was to constantly push students to be *more* creative, *more* musically adventurous – in a sense, more chaotic.
For example, the vibes player, Danny (who was not profiled in chapter four because he was not interviewed) was universally regarded as a great reader and error-free musician. Ezekiel praised him for this, saying, “Danny is so solid . . . like no mistakes from Danny. I can’t remember when I’ve seen Danny make a mistake.” At the same time, in the beginning, his solos were not as innovative as some. Throughout the course of the year, one could observe Dr. Flynn and others encouraging Danny to let loose and try something new in practice – specifically to go so far outside of his comfort zone that he would make mistakes. The group was trying to move Danny farther and farther outside of his comfort zone so that he would push the envelope in the true jazz tradition – something I watched him do with some success by the end of the study.

Edge of Chaos Summary

In mathematics class, chaos was perceived as disorder, and was the enemy. The class was orderly, the thinking processes were systematic (indeed ‘formulaic’ is more than a pun in this case), and the goal was to push through cognitive dissonance as fast as possible. In English, a state at the edge of chaos was carefully fostered by balancing what Ms. Brown described as naturally chaotic students with very specific, carefully crafted rule sets. This dynamic tension allowed cognitive dissonance to be extended to the point where it encouraged deeper analysis of questions. In the Jazz Rock Ensemble, rather than trying to contain the chaos – a function that was already served by the sheet music – the class was facilitated with the goal of encouraging and actively embracing envelope-pushing in students’ musical performances.
**Feedback Loops**

It is clear that a theme of this chapter is that these classes showed a broad range of manifestations in each aspect of complexity theory. This theme continues with the discussion of feedback loops. These three classes utilized and manipulated feedback in very different ways, from keeping the “length” of the loops relatively short and infrequent, to creating a non-stop system of whirling, intertwining, looping information.

**Geometry**

Not surprisingly, since geometry class was conducted as a relatively linear, centralized network, this system minimized feedback (relative to the other observed classes) in the same way that it minimized the “edge of chaos” aspect of nonlinearity. Certainly, there was a great deal of feedback to observe. Mr. Coughlin taught, students asked questions, and he provided a revised explanation or new example. Students took tests on which their performance was graded, which indicated to them how much of the knowledge valued in class they had, which caused them to rejoice, go to extra help, want to give up, or other responses.

Though this feedback was frequent, because it occurred in the context of the centralized network, feedback loops were fairly short: from a student to the teacher to the students; from the teacher to the students then, via one student’s question to the teacher. Generally information feedback was not much more complex than that. Occasionally, there would be multiple short loops about the same topic, for example, when more than one student asked a question about a particular problem, but rarely did feedback extend
beyond that. In groups, feedback was slightly more complex but, as previously
mentioned, many groups acted more as collections than collectives, and those that did
engage in rich discussions had limited time and a very linear goal (get the answer).

One particularly short type of feedback loop observed in this class was the “test as
a wake-up call.” Students were given a review exam that covered multiple chapters, and
most did very poorly. Mr. Coughlin interpreted this result as an en masse failure of the
students to prepare:

Not a good performance. I have my fingers crossed that a lot of you just blew it
off and said, “Na, I’m not going to prepare for it”. . . I hope that this will scare
you into preparing a little more diligently between now and the final exam.

A student then tried to ask a question about an answer on the exam, but was warned that
there were still two students taking the test in the back of the room, and:

This might come as a shock to you, but I don’t intend on giving you any of the
answers. And what I mean by that is get off your duffs, open your notebooks, go
to your textbooks. You guys are responsible for getting the correct answers . . .
and if any of you guys were wondering, “Is he going to scale the content review?”

Hell no. (in class, 4-29-08)

He then gave out an answer key and had individuals work on it silently for a few minutes.

This exchange may seem harsh on paper, but it is true that sometimes students do fail to
prepare for assessments, and with grades being a strong motivator at Metropolitan
Catholic, refusing to scale and causing students to find the answers on their own is not
necessarily a bad idea. It was, possibly, an effective use of a feedback loop. What was
also true of this exchange, however, was that it was a further shortening of feedback loops that were already restricted to exchanges between the teacher and a student or group.

_English_

Because of the agency provided by valuing student knowledge, the English class was able to set up far more complex feedback loops, not restricted only to the exchange of information between students and teacher, but also broadened to include extensive and extended opportunities for feedback among students in a much more nonlinear format. In the way of illustration, here is a brief excerpt of a Socratic seminar discussion from March 20, 2008. A student had just given a number of characteristics of an epic hero and contended that Odysseus lived up to the definition:

**Student 1 (Tom)** – I agree with you except for one thing . . . Is he really faithful to his family? He’s called a hero, and I’ll quote line 162 “Though he fought shy of her and her desire, he laid with her each night”. . . . If he was truly faithful to his family would he be doing this? . . . If he’s going to be called a hero, he has to exemplify this true faithfulness. I would have called him an epic hero if I met him and I didn’t know this about him.

**Student 2** – I agree with what Tom’s saying, but do you think that he would try to return home if Calypso wasn’t telling him to? I don’t think he’s faithful to his family, because I don’t think he would return home if Calypso hadn’t told him to.
**Student 3 (Mike)** – Calypso didn’t actually say it, like, “Get off my island and go to your family.” He’d said I want to see my family. I miss Penelope, you know, she will die soon. You on the other hand – even though she isn’t as beautiful as you – you won’t ever die, you’ll always be here, but Penelope will die at one point. She’s not saying, you know, “Get off my island. Go see your wife.” He’s trying to compel her that he has to go to his family.

**Student 2** – Yeah, but she really does influence him to go. . . I think he stays on her island because he didn’t want to leave Calypso without her understanding.

**Student 4** – I think why he didn’t leave was because he was the only person there because . . . he had no way to escape . . . he’s stuck there in captivity by Calypso. So I guess with Calypso saying, “Do you want to go or do you want to stay?” kind of gave him the leeway to be able to go.

**Student 5** – I disagree with [student 2] because . . . she’s on her own island by herself. She like never sees anyone. Why would she want Odysseus to leave?

**Student 6** – Because Hermes told her he had to. . . .

**Student 3 (Mike)** – What would make you think she would listen to him, when in the first place a nymph sleeping with a human is against, like they don’t want this to happen?

**Student 6** – Because a god is greater than she is.

**Student 3 (Mike)** – But there are already ground rules.
Soon after this, Tom and others decided that the conversation had gone too far off the topic of whether or not Odysseus was a hero and the group returned to more direct discussion of the overall question.

This exchange shows how the cognitive dissonance persisted in the group, with no one final right answer being determined. A series of interlocking feedback loops kept information flowing, however, and refinement of the understanding of the relationship between Odysseus and Calypso and the effect of this relationship on Odysseus’ status as an epic hero continued. The original student’s listing of the characteristics of an epic hero fed back on Tom who questioned whether Odysseus was faithful enough. Tom’s challenge fed back into the group, including to Student Two, who magnified Tom’s discomfort into a statement that Odysseus wouldn’t have gone home given the chance. These views fed back on student four, who reminded the group that Odysseus was effectively imprisoned, and on student five who explored Calypso’s motivation for having a captive. The final two comments seemed to concede that Odysseus was a captive and began to explore why he might be released.

Unlike the linear interactions found in geometry where the teacher would speak, student 1 would ask a question, the teacher would speak, student two would ask a question, the teacher would speak, and so on, this Socratic seminar segment showed how, in just a couple of minutes, six different voices fed back on each other, bouncing back and forth around the room in a tangle of feedback loops.
Jazz Rock Ensemble

Whereas feedback in English class was complex and intertwined, in the Jazz Rock Ensemble it was even more so: it was constant. In much the same way that the eyes, inner ear, brain, nerve fibers and muscles must be in constant communication if one is to, for example, walk across the room, all members of a jazz group must be in constant communication if the song is to work. For example, while one musician was playing, one or more of the others were “comping” or accompanying / complementing what he was doing. The musicians doing the comping had to pay careful attention to where the solo was going and make split second, often subtle adjustments from one second to the next in order to keep everything in sync. If, say, any member of the ensemble became distracted while a soloist was quieting down for dramatic effect, that accompanist would fail to quiet down with him and drown out the solo. Since such a great percentage of each tune was improvised, all seven members of the ensemble had to be giving and receiving feedback on a constant basis, or the song would quickly sound disconnected and then finally fall apart.

Feedback Loops Summary.

Again, a continuum of nonlinearity appeared in the case of feedback loops. Because of the relatively linear structure of the math class, feedback loops were small and tightly controlled. In English, feedback was intertwined and complex, and in music, it was constant. A useful analogy might be to think of information in the room as the movement of a ball. Math class would be analogous to certain kinds of baseball practice,
where the ball is thrown to the coach, who hits it, then the fielder throws it back, and he hits it again, and so on. Always the ball is traveling to or from the coach. English class is more like a game of hackey sack. The ‘ball’ moves around the group, with people responding to it in random order. The Jazz Rock Ensemble is like a complex juggling performance, where the entire group together is trying to keep a large number of balls in the air by very quickly catching and releasing them from and to all directions.

*The Butterfly Effect*

The butterfly effect is, by definition, often difficult to detect. The initial influences are so small and so numerous that one sometimes can not calculate where they came from. This is what makes predicting things like the stock market and the weather with great precision very difficult.

*Geometry.*

It is perhaps because of this difficulty that no such effect could be detected in the learning processes of the math class. By now, the picture has been painted of this classroom as a place where nonlinearity was discouraged, and the unpredictability of butterfly-effect-like learning was actively discouraged by the lack of complex feedback loops.
English.

In English, however, it was possible to see very small comments, sometimes very much ancillary to the point a student was trying to make, ripple through the group and be magnified by a process of recursive feedback. Take as an example the Socratic seminar segment quoted above. Tom was responding to the following statement by another student, who did little more than lay out a definition of an epic hero:

I think he’s almost like the perfect definition of the epic hero, because it says he seems to be able to conquer most problems he encounters, but he doesn’t use superpowers. He’s not immortal. He’s faithful to his family, his country and his god. The reason he is going home is because he’s been away from his family for so long. Then it says he is brave. Although he often feels fear, like he’s brave enough to cross the open sea to get home, but he fears that like he may die while he’s out there. He’s intelligent in the way he builds . . . his raft. . . . And then sometimes though a higher force or being will help guide him on his quest. He got help from Athena when she gave him his veil and Calypso gave him things that led him in the right direction. So basically, I think that he fits the whole definition.

From out of this somewhat rambling monologue of heroic characteristics, the group latched on to faithfulness. They could have chosen any number of factors, like, “What’s so smart about building a raft?” “What about Poseidon, who is a God working against him?” or “How brave is a guy whom we first meet crying on the beach?” Once the group took up faithfulness as an issue, however, the back and forth of the discussion amplified
its importance in the minds of the students. A small comment in the middle of a list of characteristics grew via group processes into a major topic of discussion.

Because of time and many other factors, students did not latch on to every idea that came out in discussion. In fact, Ms. Brown and I often talked about the points we were surprised the students chose not to elaborate on. The selection of important topics was left to the group, however, and unexpected topics often grew from a small ripple to eventually sweep over the entire group in the way that the importance of faithfulness did in this case.

*Jazz Rock Ensemble*

The music group showed two interesting manifestations of the butterfly effect. First, in the musical sense, the passing around of musical ideas produced a kind of butterfly effect. A musician would choose some aspect of another player’s solo and repeat it, which amplified its effect in the song. As Gary Sedopolous recognized, if it was then picked up and modified by another musician, its influence on the feel of the song was amplified further:

If, say the saxophone player starts of with a rhythm . . . if things are going well, that will surface in the same way or maybe in a little bit of a different way in somebody else’s solo . . . but also injecting their own individual themes and what not. . . It might not be in the next solo. It might not come until the drum solo [generally the last instrument to solo].
Interestingly, everyone interviewed that was associated with the music class identified a relatively small musical and social perturbation that strongly influenced the entire ensemble. This was the addition of Ezekiel Roberts. In a system of linear thinking, one would think that the influence of one member of a seven piece ensemble would change the group by $1/7$. This clearly was not the case with the addition of Ezekiel. As Dr. Flynn said:

This year . . . we brought in two new members, and one of them was Ezekiel, who’s such a live wire, but also musically, possible the best guy in the band – arguably. All of a sudden there was a new agent and the synergies were constantly surprising people so that they were – there was like electric jolts of innovation and of “what was that – we don’t do that?” those types of things. And so that was fun to watch and listen to. All of a sudden Ezekiel would assert his personality a little bit, with enough skill to it in a way that was absolutely in the moment and in the style that we were doing, and someone would be playing and just look over at him and kind of like – just a smile or even possibly follow up on what he just did.

*Butterfly Effect Summary*

Simply by its definition it is clear that the butterfly effect should be difficult to observe in “nature.” No one has ever actually identified an individual insect that was ultimately responsible for an individual tornado thousands of miles away. It is occasionally possible, however, to see some evidence of disproportionate influences on classroom systems. Though one could not detect system-wide butterfly effects in the
math class, it was clear that small ideas were significantly amplified in the English class, and that the influence of adding Ezekiel to the Jazz Rock Ensemble was both musically and socially far more important than his expected 1/7 share of ensemble life.

Nonlinearity Summary

As in previous aspects of complexity, these three classes showed great variety in terms of how they responded to nonlinearity. The mathematics class appeared to resist it strongly, maintaining formulaic thought processes and centralized networking that minimized chaotic behavior, feedback and, therefore, butterfly effects. English embraced a bounded nonlinearity, carefully maintaining a state at the edge of chaos, providing opportunities for overlapping feedback, and allowing small ideas to grow in the incubator of the Socratic seminar. Dr. Flynn actually pushed his musicians toward increasingly chaotic play, students had to be in constant, recursive communication, and this opened up the possibility for musical and social butterfly effects, not exclusive to, but exemplified by the influence of Ezekiel Roberts.

Synergy

To an educator, any talk of boundedness, network characteristics and nonlinearity are only interesting if they have some impact on learning. Only if classrooms that harness the properties of complex adaptive systems have the potential to result in synergistic learning is complexity theory worthy of the attention of educational practitioners, researchers or theorists. Given this fact, the synergy of interest to this work has been
“emergent learning,” which I define as the acquisition of new knowledge by an entire group when no individual member of the group possessed it before. The theory of complex adaptive systems suggests that this synergy should be more likely if the boundaries, networking, and nonlinearity of the group are optimized.

Geometry

True to the theory, the group that was selected because of the teacher’s admitted philosophy that “the knowledge in my class is not derived primarily from student interpretation. It has been passed down through the generations, or from a contemporary expert source” (from the teacher recruitment letter) showed little evidence that emergent learning occurred on a regular bases. Certainly, it did not happen on purpose. This is not to say that emergent learning never occurred. One may surmise that student questions caused an alteration of teacher presentation of some topic, and that this altered the group-wide understanding of that topic. But despite a diligent search, too little evidence of this phenomenon was detectable to rise to the level of trustworthiness required for this study.

English

In English class, the structure provided by tableau vivant, map making and other activities all made emergent learning much more likely. The signature pedagogy of this class, however, and the one that epitomized emergent learning was the Socratic seminar. As an evidentiary base for this assertion, it is necessary to eavesdrop on a sizeable portion of a discussion about some of the first books of The Odyssey. On February 12, 2008,
students attempted to refine their understanding of Telémachus’ decision whether or not to seek out his presumed-dead father, Odysseus:

**Student 1** – [Telémachus is] still a little boy, but that’s kind of foreshadowing that there’s still some change that he needs to go through. From line 495 to 500 it shows how he’s babied, basically, so I think later on, in another book, he will encounter a change that will make him from acting like a little boy to a man.

**Student 2** – I agree with [Student 1’s] point about the change, going from a kid to a man, but I also agree with [a previous student’s] point of him heading out on a course. I think he’s going to go out and try to find his father, but Poseidon, who we read about how he doesn’t like Odysseus. I think he’s going find about this and maybe try and do the same thing as he’s doing and Odysseus. He’s going to try to push him away from his father which will cause maybe a big conflict between Athena and Poseidon.

**Student 1** – Yeah so about [Student 2]’s point. That kind of is foreshadowing on an event that might happen in another book, because . . . that will make them kind of have a battle with each other.

**Student 3** – So do you think Athena’s going to back up Telémachus on his journey, if he goes on a journey, to get his father against Poseidon?

**Student 4** – I think that Athena will, because she keeps persuading Zeus to help Odysseus, and I think this is the best way for her to help him – by sending him out to go find him, so I think she’s going to like have a little conflict with Poseidon
and kind of like argue it out, and I think that Telémachus will find Odysseus later on.

**Student 5** – Wait -- how do you know . . . she’s really going to help, because on lines 258 to 265 he’s pretty much telling Athena that he really doesn’t know his father and even if he did, his father he wouldn’t care a whole lot. And also at the end, he’s being all spoiled and he gets tucked in at night. What type of person like that would like go out on like a dangerous adventure to help his father?

**Student 6** – How do you know that he’s *not* going to go find his father? He doesn’t know who his father is, and obviously he wants to know who he is, so he’s going to go out and search for him.

**Student 5** – Right, but I mean at the end of the Book One, they’re showing how he’s like getting all nestled up and being such a spoiled kid. Is he really going to risk going out on this dangerous adventure to find someone that he doesn’t [know]?  

**Student 2** – I think he is going to go out because he -- I agree with you he seems spoiled -- but if he was really like *that* spoiled, I think he would just forget about what Athena said. Like on line 499-500 “And all night long, wrapped in the finest fleece he took in the thought course Athena gave him.” He’s finally realizing, “I’ve got to go out and find out who my father is – that’s what I really want. So I’m going to leave this life behind.”

**Student 7 (Jim)** – And I think if it came from a god, I think you’d do it too, like what if Mary said no she wouldn’t have Jesus? That would be kind of bad,
This final comment by Jim was clearly the defining moment in the seminar. After this moment, the conversation turned in a different, more focused, more insightful direction. In the quoted section above, students were basically debating whether Telémachus was the type of person who would go out on a great quest to find someone he didn’t know. Refining their decision involved taking inventory of who stood with and who stood against Telémachus and how this might influence whether or not he would go. Interestingly, however, Athena, Poseidon and Zeus were spoken of almost as if they were Telémachus’ equals. The situation was presented as if Telémachus were caught in a conflict between rival human gangs. Though the Greeks’ understanding of gods did involve more closeness to human behavior than the Judeo-Christian understanding, Jim reminded the group that they were nonetheless still talking about gods – entities that were fundamentally different from humans and uniquely revered by them.

As a result, the rest of the discussion focused on the roles of the gods, and took a tone that recognized their special place in the Ancient Greek understanding of the world. The students in the outside ring recognized the pivotal nature of this comment and the extent to which it was the key to the entire group’s understanding of the problem when they named Jim “king of the seminar” (much to Jim’s surprise, as he said little other than this one comment). The selection of king was assigned to one or more members of the outside circle in the Socratic seminar and was intended to recognize someone who
brought up a particularly salient point, asked an especially insightful question, moved the
discussion in an interesting direction, or otherwise had a laudable role in the discussion.

So, from the course of the conversation after Jim’s comment and from the fact
that this one insight made him “king,” one can see that his linking of Telémachus’
decision to Mary’s had a group-wide influence on the groups’ understanding of the
situation, so it resulted in learning at the group level, the first requirement of emergent
learning. The next requirement for emergence, however, is that it must have been
knowledge that was not a part of Ms. Brown’s plan or of Jim’s understanding when they
walked into the room.

In an attempt to determine how this insight came about, both Jim and Ms. Brown
were shown this portion of the seminar on DVD and asked about where the ideas came
from. When asked, “Where did that [Mary reference] come from?” Jim said:

I think it just came up. I mean, I don’t remember marking that down in my book,
so I’m pretty sure I just thought of that because it’s a similar situation, you know?

It’s just a connection

When asked “Can you identify what might have stimulated you to think [of] that now,
when you might not have thought of it when you were annotating the book?” he replied:

Probably the discussion and probably because we were just talking about it in
general – and in the book I don’t think it ever came up. Like it just directly said,
“The god Athena was helping Telémachus do this.” It just didn’t say that, and
that’s how we’re kind of putting it into our own words. That’s how we’d say it.
And so then thinking about that, I guess I just thought about religion and, because that’s a big deal, and that just came into my mind.

When asked if Ms. Brown had covered a connection like this in class, Jim said she had not, and in her interview she concurred:

Never talked about Mary . . . I set up descriptions [for discussion in previous classes] so that they could see parallels between our own beliefs and these beliefs that are occurring, because they are pretty different, but . . . I’ve never given them any biblical connection, and I’ve never given them any talk about Mary. She’s not even on the God radar, really.

So clearly, Jim did not enter the room intending to talk about the connection between Telémachus and Mary and, from the discussion, one can see that the rest of the class was not making the “commanded by a god” link very clearly either. Ms. Brown had not fed them any connections between The Bible and The Odyssey. In fact, she had emphasized how Judeo-Christian and Ancient Greek visions of gods were different.

Despite the initial lack of knowledge or teacher-centered stimuli, however, the class was able to arrive at a new understanding of Telémachus’ dilemma because, as Jim put it:

People’s ideas tend to build up other people’s ideas. Maybe if somebody said something somebody else will modify it or put it in their own words, or something like that. So these kids might be saying it differently than I’d said it or with like a slight change, and then another kid will say, “Yeah, I know. This is how I think.”
The flow of the discussion, Jim’s acknowledgement that he had not thought about Mary before participating in the seminar, the fact that Ms. Brown did not cover similarities between Telémachus and Mary, and Jim’s description of how group processes generally work in Socratic seminar suggest that this device produced true emergent learning – the acquisition of new knowledge by an entire group when no individual member of the group possessed it before.

**Jazz Rock Ensemble**

Emergent learning often happened in English class, but in the Jazz Rock Ensemble, it was – to one degree or another – happening constantly. There should be little debate that hearing a new song for the first time constitutes learning. In my own case, first hearings of Mozart’s “25th Symphony” (2000, track 1), Queen’s “Bohemian Rhapsody” (Mercury, 1975, track 11) and Art of Noise’s “Close (to the edit)” (Dudley, 1984, track 4), among so many others significantly expanded my ideas about what was possible in music. Though each new tune may not produce a paradigm shift, certainly, each time one hears a new song, one has new knowledge.

How much more has one learned then when one creates a new song? Each playing of each song in each rehearsal and performance of the Jazz Rock Ensemble was, one must surmise, unique to that moment – never heard on Earth before and never to be heard again. The art of improvisation and the almost incalculable number of possibilities it provided made this inevitable. As mentioned above, each musician, when asked, “Have you ever played two exact solos exactly the same?” answered with a resounding, “No.”
When asked, “Do you think that you or anyone could come into the room and predict precisely what the song is going to sound like?” Gary responded “I can’t predict what it’s going to sound like,” and then said that the most he could predict was whether it would be good or bad based on the mood of the group on that day. Mitch was asked if he thought anyone in the world had ever played “Au Privave” exactly the way this group did, he replied, “No . . . I think every time it’s always a little bit different.” So each time this group got together to play, they created a new musical entity. Though it may have still been called “Au Privave” or “Bright Sized Life” or whatever, it was nonetheless unique because of the nature of jazz. It was, to repeat once again the definition of emergent learning, the acquisition of new knowledge (in this case a new tune) by an entire group when no individual member of the group possessed it before.

*Emergent Learning Summary*

The evidence gathered in this study indicates that emergent learning is indeed a real phenomenon, found in classrooms whose teachers did not design their curricula with complexity theory in mind. It is not, however, inevitable or manifest equally in all classes. The rigid structure of mathematics as conceived by the observed class, and the linearity of its networking reduced emergent learning to almost nothing (at least with respect to the academic curriculum). The Socratic seminar created a space in which new knowledge could be generated, and jazz demanded that students create new knowledge every time they played a tune.
About these Observations of Complexity in the Classroom

The goal of this chapter has been to provide representative vignettes to illustrate how complexity manifested itself in each of these three classrooms. Taken as a whole, the mathematics class was a tightly bounded system with little agency afforded to the students. Networking was centralized and designed to minimize disorder. With short, simple feedback loops, it did not produce significant emergent learning. Freshman English was defined by rule-based boundaries that permitted a prolonged time in the zone at the edge of chaos. Student agency was provided by the valuable insights they brought into the room and extended, nonlinear feedback loops magnified ideas in a butterfly effect to produce opportunities for emergent learning in the form of refined insight. The Jazz Rock Ensemble had loose boundaries in the form of what Dr. Flynn called a musical “minimal sketch” which allowed musicians to express their agency in the form of virtuosity. The accompanying social agency and nonlinearity in turn produced a social butterfly effect (the disproportionate influence of Ezekiel) to complement the musical ones. With networking that was multi-layered and simultaneous, chaotic behavior was encouraged and reinforced. Continuous feedback among musicians allowed emergent learning every time they played a tune. (A summary of findings from this chapter can be found in Table 3).

In chapter six, the continuum of complexity among these groups will be explored further, the consequences for practice will be examined and suggestions about future complexity research will be made.
### Table 3, Summary of Findings

<table>
<thead>
<tr>
<th>Boundaries</th>
<th>Networking</th>
<th>Nonlinearity</th>
<th>Synergy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geometry</strong></td>
<td>Tightly Bound</td>
<td>Minimal</td>
<td>Centralized</td>
</tr>
<tr>
<td><strong>English</strong></td>
<td>Defined by specific rule sets</td>
<td>Provided by the ability to contribute valued knowledge</td>
<td>Distributed</td>
</tr>
<tr>
<td><strong>Jazz Rock</strong></td>
<td>Defined by sheet music and jazz itself</td>
<td>Provided by virtuosity and emphasis on improvisation</td>
<td>Distributed / Simultaneous</td>
</tr>
</tbody>
</table>
CHAPTER SIX – ANSWERS AND FOOD FOR THOUGHT

Where the introduction to Chapter Five highlighted the fact that its purpose was restricted to discovering the presence or absence of alignment between observations in the classroom and the preconceptions of complexity theorists, this final chapter is dedicated to going beyond this dispassionate task to explore the current relevance and possible future consequences of this work. Toward that end, this conclusion will begin by revisiting the questions posed in the beginning of chapter one. Thereafter, a possibility that emerged linking the relationship between the findings of this study and the previous work of cognitive psychologists will be explored, and finally, suggestions will be made about the future of complexity research in classrooms.

The Questions

Question One: Were These Three Learning Communities Complex Adaptive Systems at all, or Were they Mere Collections of Individuals? What Factors Came into Play in Making a Class a Complex Adaptive System?

To best answer this question, it makes sense to address the second part first. “What factors came into play in making a class a complex adaptive system?” Admittedly, this study began with an a priori concept of the defining components of complex adaptive systems, derived from the theoretical and empirical literature reviewed in the first two chapters of this document. Careful attention was paid, however, to being sure to
seek out contrary evidence, and to seek new factors that may be important to complex classroom function.

During the analysis process, much effort was devoted to these two goals. Diligent efforts were made to think beyond previous concepts of complex adaptive systems and be prepared to add new factors, or reject previously theorized elements. For example, at one point in the analysis, I thought that the selective permeability of classroom strange attractor boundaries virtually erased the importance of any fractal relationships between classrooms and their surrounding systems. Upon further review, however, it is clear that the nestedness and seemingly infinite number of influences that can be observed the more one “magnifies” one’s examination of the class, mirror the properties of fractals. Also, early in the analysis, I might have said that perturbances in the system or making space in a conversation were new categories, worthy of addition to the definition of complex adaptive classrooms. In the end, however, it became clear that perturbances like adding Ezekiel to the Jazz Rock Ensemble were the stimuli for butterfly effects, and that making space in a conversation for others to speak was characteristic of the attempt of both the English class and Jazz Rock Ensemble to maintain distributed networks. In the end, no “extra” influences were discovered beyond the *a priori* codes.

So, the answer to the question “What factors came into play in making a class a complex adaptive system?” is “Complex adaptive systems are well-networked collectives of discrete agents that are: nonlinear, bounded and synergistic.” Though this is the definition proposed in chapter one, and it is true that all characteristics were found and that none needed to be added, one should not assume that therefore everything manifest
itself as expected. The interesting variances found in the defining characteristics of complex adaptive classrooms will be among the subjects of the answers to questions two and three.

Now back to the first part of question one – “Were these three communities complex adaptive systems at all?” A careful reading of the theoretical and empirical literature on complexity theory in the classroom reveals two tacit assumptions that are directly opposed to one another: that classrooms or other organizations are inevitably complex adaptive systems, or that certain conditions must be in place to consider an organization a complex adaptive system.

The observations of this study make it clear that the latter assumption is true. It is not inevitable that classrooms will be complex adaptive systems in any way that is useful to students of learning. One may say that classrooms are inevitably complicated, and I would certainly agree. One may even say that all classrooms exhibit some measure of complexity, and I might agree. To assume, however, that a class will network itself in such a way that it adapts in any meaningful way is too much to assume. The mathematics class showed little evidence that it was sufficiently complex to create the emergent learning that is the kind of adaptation at the heart of classroom complexity. To be sure, the class adapted to conditions such as snow days, unexpected losses of class time for assemblies that went over time and other disturbances, but at the heart of these adaptations were changes in teacher-generated lesson plans. The group as a whole was not involved in making the adaptation. Even if this class rose to the level of being a
complex system (which I think it most often did not), it was not a complex adaptive system.

The other two learning groups were certainly complex adaptive systems. They were well networked in a nonlinear fashion and, within their designated boundaries, produced emergent learning. As one can see from the data above, this did not mean that these two classes were anywhere near to being identical. These variances provided interesting answers to the questions examined below.

**Question Two: To What Degree was Each Characteristic of Complex Adaptive Systems Present in Each Class, and to What Extent did These Variances Result in Different Levels of Complexity among Classes?**

The first part of question two was the primary focus of chapter five so, to avoid taxing the reader with needless repetition, I instead present Chapter Five as my answer. A convenient summary of these findings can be found in Table 3, the summary of findings from Chapter Five. The second part of question number two, however, still represents unexplored territory.

In the hundreds of pages of this work, one can imagine how many times decisions had to be made about which word to use in which context. Among all of those choices, however, the most vexing has been between the word “variance” and “continuum” in the phrasing of question two, and of its subsequent analysis. After having completed this study, considering these three classes only, I am prepared to assert that I have detected a continuum in complexity along which these three learning communities reside. Given the
purposive nature of the sampling, however, perhaps it is not so surprising that such a linear relationship as a continuum was found. The math class was poorly networked, tightly bounded, excessively linear and not at all synergistic all at the same time. The English class, constrained as it was by the need to eventually move on to the next topic was as well networked, carefully bounded, productively linear and as often synergistic as it could be. Unrestrained by curriculum, the Jazz Rock Ensemble could spend the entire year refining three or four songs, which gave them even more freedom to manifest complexity than the English class had. Added to that the inherently less linear nature of music and the particular characteristics of jazz, it was the poster class for emergent learning. So certainly, a continuum in the manifestation of complex adaptive properties is possible to observe.

Having made this observation, however, I am not comfortable generalizing further to say other classes would appear along the same continuum. I do suspect that one could observe wide variance from class to class that would not necessarily place each one on an easily definable continuum. I suspect that the relationship is much more nonlinear, with subtle differences in individual characteristics resulting in very different learning results in some cases, and vast differences in some characteristics yielding learning results that were indistinguishable in others. So, though a continuum did appear in these three cases, I have retained the word “variance” in the belief that it encompasses this continuum along with many other possible observed differences in multiple dimensions of complexity.
Question Three: Could Learning in Any of These Learning Communities be Described as a Synergistic Emergent Phenomenon as Defined by Complexity Theorists? In Other Words, Could the Interactions of Members of a Group Result in New Knowledge – Not Theretofore Present in Any Agent of the System (Students or Teachers) – Being Generated by the Group, and Would that Knowledge then Feed Back Upon the Students to Result in Group Learning? If So, What Would it Look Like?

Before answering the first part of this question myself, I would like to share the answers of two of the teacher-participants. At the end of their interviews, I laid out the theory of emergent learning in brief and asked them if they had ever observed such a thing or what they thought about it. Gwendolyn Brown, the English teacher, was quite sure she had experienced the production of new knowledge in her classroom:

Yes [firmly]. Here’s an example. The question was, “After reading . . . eight books of The Odyssey, the first four is called the Telémachi, because it’s about Telémachus. What is the title of the second four set of books?” . . . They came up with . . . this term called the “emergency.” So not only was it a brilliant play on words, they really tapped into what was happening in those four books, was the emerging of Odysseus out. So they came into the room having only read the four books. They’ve read no secondary sources. . . . I never would have considered it, and it was perfect. Perfect idea.

Dr. Flynn also responded positively, but described real emergence as a rarity:

Yeah I do, and yet I think it’s elusive. I think it happens, and everybody goes, “What was that? Let’s try for that again,” and we might not achieve it when we
try for it the next time, and I don’t mean to say that it happens when you’re not trying for it, although sometimes that’s true, but what I do mean that it’s not always there, and that’s why they’re students. They can’t always get to that plateau. Professionals get to that plateau much more frequently, although, I would say, not always. And I think that – in a sense it’s called being “in the zone” – those types of things.

An astute reader may notice that I have described emergent learning in the Jazz Rock Ensemble as constant, while Dr. Flynn refers to it as “elusive.” Though these two contentions appear to be at odds, they are, in fact, not. In the above quote, Dr. Flynn is simply holding emergence to a higher standard than I have. He talked about being “in the zone,” which is a special level of emergence, on a higher plane than the minimal definition I provided. I continue to assert that every time students played a tune, they created a new entity, and therefore experienced emergent learning. I also agree with Dr. Flynn that this process can reach a special level, when the tune comes out really well, which is when emergence is easiest to detect.

Mr. Coughlin, of course, had no examples of emergent learning to give, but he did think that nonlinear processes would be more appropriate in other classes. When asked if he would make any changes to the statement he received in the recruitment letter about believing that knowledge was passed on as opposed to generated in the classroom, he said, “If I’m teaching a history class, I don’t think I feel comfortable with that. I wouldn’t feel -if I’m teaching history, I wouldn’t feel good if that’s how I saw myself as a history
teacher.” As a teacher of lower-level math classes, however, he felt that the linear transmission of knowledge was an appropriate pedagogy.

So, as the evidence above shows, emergent learning is a very real but, as Dr. Flynn highlighted, not at all inevitable phenomenon. So, a simple examination of, “What would it look like?” already covered in previous chapters, is subsumed by the more praxis-oriented imperative, “By what mechanism does emergent learning occur?” This will be the focus of the following section.

**Facilitating Emergent Learning**

Ultimately, the findings of this study suggest that the fostering of emergent learning is about balance. The Venn diagram in Figure 6 shows the three major factors that contribute to emergent learning. Given that complex adaptive systems are well-networked collectives of discrete agents that are: nonlinear, bounded and synergistic, it is clear that the synergy (emergent learning) occurs.

*Figure 6 – Balance and Emergence*
at the intersection of nonlinearity, boundedness, and networking. In this diagram, this area of synergy is represented by the somewhat triangular space containing the gray dot. A more accurate representation of the nature of emergent learning can be derived by imagining that the same diagram is instead an oddly shaped table, seen from a bird’s-eye perspective, balancing on a single point directly under the middle. Now imagine that the grey dot represents learning and that it is a marble that can only produce emergent learning when it is in the somewhat triangular space at the center of the table. Should the marble roll outside of the central triangle, there may still be learning, but it will almost certainly not have emergent properties. My observations, consistent with previous theories of optimizing complex adaptive systems, indicated that should the balance among boundaries, networks and nonlinearity be optimized, there was a high probability that the table would remain level, the marble would remain at the center, and emergent learning would be possible. Should any part of the table gain or lose too much weight (literally in the case of the table, or in the sense of importance or quality in the analogy) the balance would be disrupted, the marble would roll out of the center of the table, and learning would move outside of the space where emergence could occur.

For example, in the observed math class, nonlinearity was minimized, both in terms of classroom structure and thinking processes. Step one led to step two which led to the one and only answer. The teacher was the focus of the class, and communication occurred in separate direct lines, extending from him to individual students, but rarely between students. As a consequence, networking was minimized, and strong boundaries such as rigid rules regarding communication and formulaic approaches to information
dominated. The table tipped at a high angle toward boundedness, and the marble (learning) was at all times far from a space where it could be emergent.

In the case of the Socratic seminar so frequently observed in the English class, however, the boundaries were specifically designed to optimize nonlinearity and healthy networking, so the table remained balanced, and there was a high probability that the marble of learning would remain in the center, producing a condition that made emergent learning possible. Similarly in the jazz-rock ensemble, the nature of jazz, the structure of the class and the particular sheet music from which students were playing created a boundary that allowed strong inter-musician networking, and nonlinear interpretations of the music. The table was balanced, the learning “marble” was in the synergistic zone, and as a result, a new interpretation of the song, likely never before present on the Earth, emerged from the system.

Frustratingly for practitioners, there is likely no more formulaic description possible of how to facilitate emergent learning. The two classes in this study achieved this balance using very different techniques, each one customized to its subject, goals and the characteristics of the group. It is likely that other classes would have to execute similar customization, given their local needs and attributes, all the time focusing on balancing boundaries, nonlinearity and networking. What this study is able to provide for practitioners is a reassurance that attending to these group characteristics can result in emergent learning. At the same time, these English and music groups provide good examples of how real classes successfully fostered emergence.
Who Cares About Emergent Learning?

In the course of this work, emergent learning has been theorized, documented in classrooms, examined in different forms and shown to be about balancing various factors. The most pressing unanswered question remaining is, “Who cares?” Who benefits from emergent learning and under what circumstances? The most simple answer, provided by the definition of emergent learning, is that it allows teachers and their classes to exceed their own knowledge and produce learning that the teacher could not impart by transmission, in some cases because he or she did not know it. Ms. Brown would never have thought to call books five through eight of *The Odyssey*, “emergency,” but once that idea popped up in Socratic seminar, both she and her students were edified by it.

So the power of synergy is present in emergent learning, but do all classes need or want that type of learning? The answer is, “No.” According to the observations made both in this study and in others, the power of emergent learning lies in its ability to help groups achieve higher levels of cognition. (Figure 7 uses an adaptation of Anderson’s (2005) refinement of previous cognitive taxonomies to illustrate this point.)\(^{11}\) Harnessing the power of complexity in classrooms keeps groups of learners in the synergistic zone (as illustrated in Figure 6) for extended periods of time. This allows them to achieve higher levels on Anderson’s taxonomy, achieving ever more refined levels of cognition. Jazz musicians were encouraged to get to the point where they could “create” new tunes. English students “created” maps of Homer’s world, retelling the story of *The Odyssey*,

\(^{11}\) Anderson’s work expands Bloom’s taxonomy much more extensively than is indicated here, but his levels of cognition have been presented in the pyramidal format often used to present Bloom’s work for convenience. Also, I have added the category “know nothing” as that is the basic state from whence cognition springs. Also, I do not interpret the taxonomy as a series of steps that must be climbed, but a set of cognitive skills that can be achieved in almost any order.
they were encouraged to “apply” their learning to their real life experiences, to “analyze” the messages in the story, and to “evaluate” each other’s perceptions. The goal of these two classes was to produce learning at the top of the pyramid, and the design of their pedagogies allowed ample time in the synergistic zone which allowed the groups to maintain cognitive dissonance long enough to make achieve higher cognition together. For teachers wishing to see their classes reach these higher levels of cognition, emergent learning is a singularly powerful phenomenon.

What of geometry, however? It was never the goal of the geometry class to spend a lot of time getting to higher levels on the cognitive taxonomy. The goal of geometry was to provide a fundamental “understanding” of how to “apply” a large number of mathematical tools from a toolbox. Given that goal, investing time in facilitating emergent learning would simply take away the number of basic tools that could be
provided to these students in the given time. Mathematics educators may argue about whether or not this was the appropriate goal, but the fact is, if one’s goal is to impart a large amount of low-level learning in a small amount of time, emergence is unlikely to be helpful. It is for this reason that, though Mr. Coughlin’s geometry class has been presented as lacking in areas of interest to this study, it was not lacking as an educational system. It was simply a class that was well designed to execute the goals implied by the department’s curriculum document: provide students with a large volume of basic knowledge in a short amount of time.

The point of this section has been that attending to the characteristics of complex adaptive systems has great potential to produce synergistic results – lifting the power of teaching and learning in classrooms even above the knowledge of teachers. In particular, the use of complexity theory as a guiding principle when designing pedagogy holds extraordinary promise with regard to providing students with ever more advanced levels of cognition. If these advanced levels are not the aim of a particular course, however, there is no reason to believe that a complex pedagogy would be of much use.

A Few Practical Considerations Regarding Complex Adaptive Classrooms

One of the points of this study has been to demonstrate that there are complex adaptive systems at work in schools, even in classrooms that were not designed with this theory in mind. At the same time, the data presented here demonstrate that complexity does not appear to the same degree in all cases, and that it may often be, for all practical
purposes, absent. It is worth considering what forces in contemporary schooling might contribute to how much complexity is or is not possible in a learning community.

One pressure that clearly works against complexity is an emphasis on large volumes of content with less emphasis on the thinking skills that should be attached. The math class under study, for example, was under pressure to cover many topics in a very short time. The geometry curriculum map was a long litany of items to be checked off each month. These goals, standardized across the department, left the teacher with little option but to move quickly, taking little time to work on higher-order thinking skills, making thoughts of complex pedagogies useless.

This pressure was derived from teachers’ concepts of mathematics, the approach of textbook companies, the college admissions process (along with its standardized testing regimen), parental expectations of rigor and any number of other factors. In this school, many of the pressures are local and could change relatively quickly if, for example, a new department chair or consultant like Davis problematized the current view of math. How much more difficult must it be to think in terms of complexity when curricula are standardized from afar? Most public school teachers have little influence over the number of topics they must cover, the intellectual approach that can be taken to a subject in their class, or the time they have to facilitate learning. All of these things are controlled, at least in part, on the state and federal level, with particular pressure being provided by the standardized testing associated with No Child Left Behind.

Still, that pressure may not have to be all bad. If tests demanded more higher-order thinking, they may influence school departments and teachers to seek out more
ways to help students focus on the top of Anderson’s taxonomy, a goal for which complexity thinking is particularly well suited.

Controversies in Complexity Research

*The Role of Randomness*

As with any other area of research, there is no lack of controversy among complexivists. A particularly hot topic is whether researchers are trying to apply complexity theory inappropriately simply because, in some circles, it is the fad of the moment. I have already made that criticism in my review of Nelson’s (2004) work in Chapter Two. My critique of Nelson’s work was based on the fact that it was too individualistic and did not study group-level emergent learning.

Others are even more critical of a much larger portion of complexity research, asserting that researchers are trying to attribute purposeful behavior to inherently random systems. Perhaps the most bluntly stated of these critiques was written by John Paley (2007), who complained that this mistake was being made in research on nursing. He believed strongly that “trying to import intentionality into complexity theory rather misses the point” (p. 235), since his view of complexity requires that the elements of the system follow “simple rules, unaware of the complexity they are producing, and making no reference to any centralized blueprint” (p. 235).

In Paley’s view, this study of three classrooms presumably would be pointless and its conclusions a terrible stretch of complexity science. To prod the research community on this point, Pat McQuillan began an email conversation among some of the great minds
in complexity research, including Bill Doll (oft cited in this work and in the larger body of complexity research) and Barney Ricca (the chair of the American Educational Research Association’s Chaos and Complexity Special Interest Group). McQuillan provided two quotes from Paley (longer versions of the ones I used above) and asked them to comment.

Ricca quickly responded that he liked some of the issues that Paley brought into focus:

Two things are, as far as I can tell, important in CAS. The first is a real paradigm shift in that order can come from no plan at all. This is, for me (and for most of the "natural" scientists) the huge change in world view: We don't need centralized control to create something. The second is that the "emergent" order can not be "derivable" (or foreseeable, or planned, or predicted) from the nature of the interactions between the various agents of the CAS. (personal communication, October 8, 2008)

Dr. Sarah Pratt of the University of North Carolina further expanded this idea when she asserted that:

[I]t is only in reflecting back on our actions that we can acknowledge whether complexity did in fact emerge. We cannot assume that if we "set up the right conditions," that complexity will result. The idea that we can "produce complexity" is often espoused by those who still maintain a rationalist, modernist perspective that assumes cause-effect relations. (personal communication, October 9, 2008)
If order comes from no plan at all, if complex adaptive systems may not use blueprints, and if one can only reflect upon complex adaptive systems after they have appeared rather than try to foster them, where is the place of the research described in this dissertation, and are the suggestions I have made “rationalist?” Do they “assume cause-effect relations?”

In fact, I agree with Paley that complex adaptive systems follow simple rules, are often unaware of the magnitude of their own complexity, and do not follow a rigid blueprint in the traditional linear sense. I think that Dr. Ricca is correct in suggesting that emergence is not strictly predictable, and that Dr. Pratt was correct when she asserted that one can only know for sure if a complex adaptive system resulted by looking back on it. As Paley (2007) conceded, however, “the environment is . . . what a complex adaptive system adapts to: the rules which agents follow tell them . . . how to respond to environmental stimuli” (p. 236, italics added).

In putting forward the conclusions and principles for classroom facilitation I have suggested in this dissertation, I acknowledge the unpredictability and spontaneous nature of complex adaptive systems, but insist that teachers are dominant influences on the environment of the classroom, and that complex adaptive systems of students then respond to that environment. Ecologists speak of keystone species. Very simply put, these are organisms that have a disproportionate affect on their ecosystems. The classic example is the beaver. The fact that it builds dams creates a new environmental condition (a pond) that nearly entirely precludes the presence of any number of
phenomena (cactus growth to take it a bit too far) and makes others much more likely (the presence of wading birds, for example).

Teachers are the "keystone species" of the classroom, influencing the environment, but not determining precisely what will happen within the CAS (the class or the individual students, depending on one's chosen grain size). Just as the beaver does not determine what precise plants and animals will be present or what exactly they will do from moment to moment, the teacher can not control student learning in a rigidly precise, linear "if I do this activity, students will learn precisely this" kind of way. As a keystone actor, however, the teacher can influence the environment in which the CAS forms, both influencing the likelihood that it will form at all and making it more likely that it will accomplish particular goals. Since the environment can, according to Paley, have some measure of intentionality, a teacher can practice what Levinthal and Warglien (1999) call a kind of "landscape design," where they set the stage upon which the CAS plays out. The nature of the environment in which the CAS forms then influences (not directly determines) what outcomes are likely.

Dr. Doll began the email discussion by complimenting the points that Paley made, but when I asked if his 1989 research with math teacher Ron represented an attempt at environmental control and, therefore, a measure of intentionality, he responded:

[I]f we will loosen that desire for prediction and control a bit; if we will allow space for interactions to take place, then (Under Certain Conditions) creativity can blossom and the new can emerge . . . [I]t is the lessening of the bonds of control (moving to that place far from equilibrium) that is necessary for the not-yet-seen
to emerge. This space is, as we all know, a delicate one, near, maybe even on but never over, the edge of chaos.

All the above has [been] guided by working with students in a variety of situations. For me, the examples you give are illustrative of what I was hoping to accomplish. And as an educator, a committed one, I do wish to accomplish – setting up a rich environment which I believe is a *sine qua non* for creativity to emerge. And in that environment we all are co-learners, co-creators, co-operators.

(personal communication October 10, 2008)

Even Dr. Ricca, perhaps the most enthusiastic proponent of the unpredictability of complex adaptive systems, upon reading a very brief summary of this dissertation research, said:

> The way out of these conundrums [whether or not one can do *any* prediction or manipulations of complex systems] is, I believe, recognizing that with Jazz, as with a good classroom, there is no long term prediction (nor is there an attempt to do so). Instead, there is a series of very tight feedback loops, and these do allow for some "control" of an otherwise chaotic system. (personal communication, October 10, 2008)

Later, after reading a more elaborate explanation of the idea of a teacher as keystone species, Ricca, though still advising an abundance of caution, wrote, “To a large extent, I'm intrigued by the notion of teacher as a keystone species, and I think that it is worth some further thought” (personal communication, October 17, 2008).
Though there is controversy in the complexity community about the ability to manipulate, generate, or predict complex adaptive systems, I am confident that this study provides evidence that teachers can manipulate the *environment* in which a complex adaptive system of students then forms. This environment both influences whether or not the system is likely to form and in what general intellectual direction it will go. This is not an overly deterministic stance, in that I do not presuppose that one can predict exactly what outcomes will be produced by these systems. I only contend that, since complex adaptive systems, by definition, adapt to their environments, the environs in which student groups are placed can change the probability that certain general types of learning can occur.

*The Controversy that Should Be: Ethics and Power*

This study has, like its predecessors, taken a largely dispassionate look at a sample of classroom systems. Care has been taken not to judge the value of teachers’ choices of curricular goals, only how compatible they were with complexity theory. The diversity of intellectual contributions has been valued without making judgments about the various backgrounds from which these perspectives originated. The school has been described so that readers may compare with their local situations, but the relatively unique features of the school have not been explored much further. This kind of science-like attempt at describing complex adaptive social systems has merit, in that it allows a system to be described simply in terms of its value as an exemplar of a little-understood phenomenon: a complex adaptive system.
In the future, however, as complex adaptive social systems become better understood, it will be vital that complexity studies examine issues of power, social justice, and other ethical matters. Though complexivists make analogies about anthills and machines, classrooms and other social systems are so much more. If the complex adaptive system of an anthill falls apart, or if a machine breaks down, there will simply be another anthill or a new machine to study. When classrooms and social systems fail, however, there are far more serious consequences. Human lives may be altered forever.

Moreover, truly understanding human complex adaptive systems will require a deep understanding of power structures, whose voices are valued, and who is affected by the workings of these systems. For example, the school under study represented an undeniably privileged situation. Students were selected from among hundreds of applicants and everyone in the community recognized that the point of the school was to create something different, perhaps something more, than students’ local public schools. Did the fact that students were pre-identified as gifted by virtue of their admission make English teachers more likely to emphasize meaning-of-life-oriented goals than simple grammar and basic exposure to literature? Was the mathematics curriculum so content-oriented because of teachers’ confidence in students’ ability to learn at great speed? Do other schools (and their students) have the resources to sponsor an elite jazz combo? Could students in other schools afford the instruments and private lessons that made this group so successful?

Future studies must compare not only different classes in the same school, but classes in different social environments. More than this, the future of complexity theory
research must live up to its own recognition of the importance of agency by investigating the forces of race, class, socioeconomic status, geography and other social constructions that influence who is given a voice in our schools. Ultimately, it is not enough for complexity theory to declare that agency is critical to the proper functioning of complex adaptive systems. We must partner with critical theorists, feminists, queer theory researchers and others to examine what the nature of agency is in our schools. Who gets to participate in creating knowledge in groups, who is left out, and to what degree?

Once complexity theorists engage in this discussion, there will be much that is worth sharing. Not only will complexity lose some of its cold detachment from social realities, but it may be able to suggest mechanisms to work on our social problems. For example, perhaps desegregating schools is, by itself, not much better than putting a lot of different kinds of people on an elevator – they form only a collection of diverse people. If schools paired this practice with an attempt to create complex collaboratives of students – groups that create identities for themselves which influence the identities of the individuals which then feed back on the identities of the groups and so on – schools would become truly integrated and truly effective learning systems.

Suggestions for Future Research

Though well substantiated by the observations of the classes in this study, much more research would be needed to establish the relationship posed in Figure 7. This relationship between a cognitive taxonomy and time in the synergistic zone has been implied in some previous research, but requires more examination before it is adopted
with any level of trustworthiness. For that matter, more research is required in the
relationship between complex adaptive systems and learning in general. Complexity
theory has become somewhat popular among researchers of school and district
leadership, but has not yet attracted the attention of many who research cognition and
learning.

As chapter two highlights, very little empirical work has had as its primary goal to
examine groups of K-12 students through the lens of complexity theory. Perhaps this is
because most educational research is conducted by teacher education professors, so they
have an interest in and easy access to teachers. Perhaps it is because the special ethical
status and sometimes unreliable behaviors of minors make them challenging to study. It
would be a shame, however, if the reason researchers avoided studying complexity in
groups of young people was that they did not think K-12 students were capable of the
level of thought and agency that is required of the parts of a complex adaptive system.
The thoughtful and insightful statements of student-participants in this study indicate that
they are entirely capable of sharing valuable data with researchers, and that they are more
than capable of being agents within complex adaptive learning systems.

In addition, more research that takes the etic stance is required. Studying classes
that are not designed with complexity theory in mind gives researchers a glimpse into
ways that complexity already is (and is not) being harnessed in schools. This gives
researchers a pathway to praxis, in that it allows them to recognize what is already
working in schools, what language is already being used to describe positive
characteristics, and generally how to communicate to teachers and students in a way that
is more likely to result in concrete benefits. Toward that end, and toward the goal of determining whether there is a variance or a continuum in complex characteristics, it would be interesting for future research to choose classes more randomly. This purposive sample was designed to provide a first glimpse into the variety of manifestations of complex adaptive systems in classrooms, but with this data collected, it would be interesting to expand beyond a sample specifically designed to choose presumed extremes of complexity.

The most pressing imperative in complexity research is to recognize that complex adaptive systems do exist in classrooms and that those class systems are made up of students. Even researchers of societal influences, government policies, school leadership, teacher induction and other fields must recognize that the ultimate site of praxis is in the classroom with the students. Failing to directly study this environment more extensively severely cripples the research community’s ability to affect teaching and learning – the central focus of education.

Conclusion

Students can learn some very basic things in relative isolation: that an object is hot, that candy is tasty, that crawling too fast burns the knees, and other basic information. As Vygotsky (1978) observed, however, in order for students to achieve higher learning – that type of learning that is uniquely human – the acquisition of knowledge must be socially mediated. In short, humans need to be taught. As the eighteenth century philosopher Rousseau (2000) suggested, this learning can come through a tutoring relationship. In Rousseau’s mind, tutoring was the ideal and schooling
students in groups would actually be counterproductive. He went so far as to suggest isolating his ideal student, Emile, from too much social interaction. By “keep[ing] the child in sole dependence on things,” the tutor “will follow the natural order in the course of his education” (Rousseau, 2000, p. 67).

Social learning theories reject Rousseau’s isolationism and suggest that social interaction can be a powerful tool in education. The fact is that, even if no theorist thought schooling in groups was a good idea, of what practical interest would this be in modern American education? Students go to schools where they are grouped together, and there is neither the money nor the motivation to tutor all of the United States’ 79 million students (Davis & Bauman, 2008). Given that students learn in groups, it is clearly worth studying these group dynamics.

As explained in Chapter Two, other theoretical frameworks have examined group learning. The particular contribution of complexity theory is the idea that a class can be more than an information receiving device, but can also be a knowledge-generating system. The intellectual revolutions of the nineteenth and twentieth centuries in the natural sciences, mathematics, psychology and other disciplines have broadened the human consciousness to the point that we now understand that simple, linear cause and effect relationships are not the norm in complex systems such as schools, classrooms and individuals. Often, this nonlinearity causes researchers to emphasize how unpredictable school situations are. Going too far down this road is too nihilistic to be useful however. It is important to understand that learning can be unexpected and emergent, but there is little sense in dwelling on how hopeless it is to make precise predictions.
This study has examined the emergent properties of complex systems in search of how this emergence may be used not as a source of despair about how unpredictable schooling is, but as a generator of powerful learning opportunities. Emergence as examined in this work is as unpredictable as it is in the rest of complexity theory, but this study represents an effort to use recognition of the properties of complex adaptive systems to encourage synergistic learning results that make the classroom a more productive place. If the observations made at this school are indicative of the workings of other classes in other places, attending to networking of human minds, nonlinearity of expected outcomes, and appropriate boundaries that foster nonlinear networks, learning communities may produce new knowledge that exceeds the wisdom of even the teacher. They may act as active producers of knowledge, rather than as simple receptors of the wisdom of others.

Though teachers can not strictly control the outcomes of the complex adaptive systems that may form in their classrooms, they can work to create environments where those systems can flourish, and create the conditions to which the complex systems will adapt. In that way, they can still direct learning in a general way, while providing an environment that is close enough to the edge of chaos that emergent learning may result.
References


Hedegaard, M. (2007). The development of children's conceptual relation to the world, with a focus on concept formation in preschool children's activity. In H. Daniels,


Strayhorn, B. (1941). *Chelsea bridge*. [Music score].


## Appendix A

### A Collection of Definitions of Complex Adaptive Systems

<table>
<thead>
<tr>
<th>Authors</th>
<th>Complex Adaptive Systems Definition</th>
</tr>
</thead>
</table>
| Bloch (2004) | - Open exchange  
- Networks  
- Phase transitions between chaos and order  
- Fitness peaks  
- Nonlinear dynamics  
- Attractors, bagels and emergence (A bagel is a torus attractor, where things keep going around and around, while never exactly repeating.) |
| Bloch (2005) | Characteristics of complex adaptive entities  
- self-maintaining though their components, even shapes, may change  
- open  
- part of networks  
- parts or fractals of other entities  
- dynamic, experiencing phase transitions between chaos and order |
| Carr-Chellman (2000) | Underlying concepts of the new science  
- perturbation (concious creation of dissatisfaction  
- Self-organization (control of the whole is derived from the interactions of the whole)  
- Dissipation of Rigid Structures (heirarchies, patterns of interaction, etc)  
- Sensitivity to initial conditions (butterfly effect) contributes to our understanding of the limits of prediction  
- Entropy (managed short-term by the building of boundaries, but living systems require large dissipation of energy to maintain functions)  
- Bifurcations (turning points that are the result of perturbation)  
- Attractors |
- internal redundancy  
- internal diversity  
- neighbor interactions  
- decentralized control  
- enabling restraints |
| Clarke Collins (2007) | Characteristics of CAS  
- exhibit networked rather than heirarchal structures  
- feedback loops  
- capacity for self-organization or self-regulation  
- disequilibrium  
- nested nature (fractal character) |
Terms collected from Capra:
- disequilibrium
- order and chaos
- self-organization
- ecology (D&S concept that knowledge and nature are not separate)
- evolution
- emergent properties (synergy)

Collins (2004)

"Complexity science deals with self-organizing, self-maintaining, adaptive phenomena - in brief, with systems that learn" (p. 295)

List of qualities necessary for a complex learning system
- self-organizing
- relationships tend to be short range
- bottom up emergent
- exhibits transcendent properties not manifest in individual agents
- embody their histories
- complex forms are often nested, with forms distinguished according to group size and evolutionary pace (drawn out in figure 1 on p. 296)

Davis Simmt (2006)

Conditions necessary "for the emergence of co-activity that might give rise to previously unrealized orders of organization" (p. 309)
- internal diversity
- internal redundancy
- decentralized control ("is only possible if the phenomenon is framed by constraints that enable unanticipated possibilities. Complex systems are rule-bound, but those rules determine only the boundaries of activity, not the limits of possibility" (p. 311)) [strange attractor?]
- enabling constraints
- neighbor interactions (these neighbors are not people but ideas; must be sufficient density)

Davis Sumara (1997)

Distinguishing characteristics of complex systems (from Waldrop (1992))
- capacity to undergo spontaneous self-organization
- adaptive
- more than the sum of it's parts, it learns.

These are cobbled together from throughout the paper, and not presented as a definition
- self-organizing
- nested
- transcend their components
- adaptable, dynamic and robust

Davis Sumara (2001)
Necessary qualities to be classified as complex
- self-organized
- bottom-up emergent
- short-range relationships
- nested structure (aka scale free networks)
- ambiguously bounded (open)
- organizationally closed
- structure determined (can change their own structures; embody their histories; "they learn - and are thus better described in terms of Darwinian evolution than Newtonian mechanics (p. 6))
- far from equilibrium

An admittedly partial list that represents what he was trying to do in this particular class
- boundaries / attractor area
- self organization
- occurs suddenly and spontaneously
- occurs only when there is a difficulty to overcome (Piaget called this "disequilibrium")
- there are bifurcation points - critical junctures when re-organization occurs.

good complex adaptive systems
- open
- organic
- nonlinear
- self-referencing
- have strange attractors

Characteristics of CAS
- nonlinearity
- dynamic behavior
- emergence and self-organization

Chaotic complex systems are:
- nonlinear
  - attractors (fixed point, limited cycle, and strange)
- dynamic
  - open
  - dissipative
  - stability - bifurcation - chaotic period - new, more complex order
  - self organizing
  - self-similar (related to fractals)
Characteristics of CAS
- agents
- self-organization
- nonlinear
- interconnected
- far from equilibrium
- self similarity [like some fractals]
- co-evolution
- control parameter
- phase space [I think this and the previous are just set ups for]
- attractor

"In a complex adaptive system, independent agents dynamically interact with and adapt to one another and the environment" (p. 41)

Holland's Model
- Four properties
  - aggregation
  - nonlinearity
  - flows (of information)
- diversity
- Three mechanisms
  - tagging
  - internal models (develop from interactions through)
    - reproduction through fitness
    - recombination through cross-over
    - replacement
  - building blocks [small # of inputs, when combined, make many possibilities - aka DNA]
complex adaptive systems can be regarded as a collection of information-gathering entities (agents) which:
1) Respond to the environment
2) Respond to one another
3) Segregate information from random noise
4) Compress regularities into a model
5) Modify their internal characteristics—i.e., adapt to improve their performance of desired tasks

Typically, complex adaptive systems:
6) Possess intrinsic nonlinearities which can lead to either negative or positive feedback
7) Display emergent (self-organized) behavior
8) Are unusually sensitive to initial conditions
9) Are rarely capable of finding an optimal state; instead, get “stuck” in local minima.
10) Finally, intervention in the affairs or behavior of a complex adaptive system often gives rise to unexpected consequences

Blair's theoretical concepts associated with chaos theory in educational systems:
- butterfly effect
- onset of turbulence
- dissipative structures
- strange attractors
- recursive symmetries (feedback)

"Firstly, a complex system can be described as a collection or grouping of elements or components that are all either structurally or functionally connected and interdependent. The whole system cannot be reduced to the sum of its parts" (p. 171).

Includes the following elements, though they are not organized as a definition or as elements of a CAS:
- emergent properties
- self-organization
- sensitivity to initial conditions (butterfly effect)
- fitness peaks
- In my opinion, he describes a kind of strange attractor effect "during the life of the organism every cell undergoes a change (i.e., a molecular turnover) even though the organism itself remains stable. . . Organisms are dynamic fields" (p. 173)
Citing Kelly (1994) "complex systems are adaptable, evolvable, resilient, boundless, and novel" (p. 69)

From Davis & Simmt (2003) Necessary but insufficient conditions to be capable of innovation:
- internal diversity
- redundancy
- decentralized control
- organized randomness
- neighbor interactions

Sinclair (2004)

CAS definition
- cellular autonoma (indepentent parts following simple rules
- dissipative structures
- Autopoiesis / openness

Smitherman (2005)
## APPENDIX B

*A Summary of Empirical Research on Complexity Theory in the Classroom*

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study Type</th>
<th>Sample</th>
<th>Method</th>
<th>Research Findings</th>
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</thead>
<tbody>
<tr>
<td>Clarke (2005)</td>
<td>Action Research / Self-Study</td>
<td>36 pre-service elementary teachers in an alternative to the usual program at University of BC (CITE Community and inquiry in teacher education)</td>
<td>Remembrances from teaching in the cohort.</td>
<td>CITE is a complex adaptive system.</td>
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<tr>
<td>Clarke Collins (2007)</td>
<td>Case Study</td>
<td>1 Kindergarten class, its teacher and student teacher.</td>
<td>60 observations (videotaped) over 8 yrs. Researchers engaged in conversation and participated in activities. Also mention another teacher upstairs who is fictional and only included as a counterpoint.</td>
<td>The practicum is a complex adaptive system as defined by their criteria, nested within other complex systems.</td>
</tr>
<tr>
<td>Collins (2004)</td>
<td>Collaborative Action Research</td>
<td>Grade 1/2 class of 22 students and their teacher.</td>
<td>Observations</td>
<td>Participatory democracy in the classroom is consistent with complexity theory</td>
</tr>
<tr>
<td>Authors</td>
<td>Study Type</td>
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<tr>
<td>Dalke et. al. (2007)</td>
<td>Self Study</td>
<td>A group of teachers in a two-week summer institute on &quot;emergent pedagogy&quot;</td>
<td>Observation</td>
<td>The students learned about emergence, learned in an emergent way, and designed lesson plans to encourage emergence.</td>
</tr>
<tr>
<td>Davis Simmt (2006)</td>
<td>Collaborative Action Research</td>
<td>26 Canadian teachers of mathematics, incl. all grade levels and levels of experience. Two are specialists and the others are general.</td>
<td></td>
<td>Cohort met for daylong seminars every few months for unspecified # of yrs. Viewed by teachers as professional development opportunities. Teachers worked on shared interpretive and problem solving tasks of their choosing. Researchers facilitated and observed (presumably).</td>
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<tr>
<td>Authors</td>
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<tr>
<td>Davis &amp; Sumara (1997)</td>
<td>Collaborative Action Research</td>
<td>&quot;most of the teaching staff of a small urban elementary school&quot; (p. 112)</td>
<td>Year long study. D&amp;S facilitated semi-monthly &quot;learning seminars.&quot; Soon expanded to parents and then to co-teaching experiences. (D co-taught fractions to grade 3/4. S co-taught a novel to 5/6). Video recordings and transcripts of the classroom portion.</td>
<td>&quot;it was not unusual for the activity in the classroom to take completely unanticipated but (in terms of the subject matter) appropriate turns. Insights would &quot;spread&quot; throughout the room&quot; (p. 115)</td>
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<tr>
<td>Authors</td>
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<tr>
<td>Davis &amp; Sumara (2001)</td>
<td>Collaborative Action Research</td>
<td>Entire faculty of McKenzie Elementary School. Previous faculty had been disbanded and this collection of experienced educators was new.</td>
<td>Facilitate meetings and examine transcripts and audiotapes.</td>
<td>“the experiences of alienation between school and surrounding community were largely overcome” (p. 87)</td>
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<td></td>
<td>They were observing the genesis of a community from a collection to a collective [my words in this instance]. People started speaking in terms of &quot;we&quot; instead of &quot;me&quot;</td>
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<td></td>
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<td>This was occasioned largely by the spontaneous differentiation of roles (cited as an example of self-organization)</td>
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<td>Authors</td>
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<tr>
<td>Davis Sumara (2007)</td>
<td>Action Research</td>
<td>32 pre-service teachers in a teacher ed English methods class</td>
<td>Vignettes from their teacher ed classes.</td>
<td>Margaret said &quot;it's interesting how our final poem developed on the screen. I don't think that either of us could say who wrote what&quot; (pp. 61-62) &quot;although Davis did anticipate some of the outcomes . . . Many of the details were unimagined and, arguably, not-yet-imaginable&quot; (p. 63) &quot;complexity science compels us to attend much more to the creativity and intelligence of emergent collectives such as classroom groupings and societies that [sic] to the abilities of individuals&quot; (p. 59)</td>
</tr>
<tr>
<td>Authors</td>
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<tr>
<td>Doll (1989)</td>
<td>Action</td>
<td>one grade six math class, including the teacher and researcher-co-teacher</td>
<td>co-taught the class once per week using the principles of complexity (particularly chaos theory) to guide their pedagogical design</td>
<td>&quot;whether on observer saw randomness or progressive order depended on whether that observer was in the class for a few minutes or for the whole period&quot; (p. 66)</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>This class was talented ‘in the top 3 percent among schools serving students with similar backgrounds” (p. 66) in California</td>
<td></td>
<td>&quot;problem solving may well hinge on this factor of understanding the structure of the problem” (p. 68)</td>
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<td>&quot;letting the students make up their own patterns, provided excellent drill and substantive insights into the nature of fractions and their relations with whole numbers” (p. 69)</td>
</tr>
<tr>
<td>Authors</td>
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<tr>
<td>LaRoche, Nicol, Mayer-Smith (2007)</td>
<td>Self-Study</td>
<td>19 pre-service elementary teachers and their students</td>
<td>Taught the science methods class and observed the process and work product when pre-service teachers and students were assigned the task of producing a video about science.</td>
<td>Claim to have utilized characteristics of complexity such as self-organization, chaotic attractors, fluidity, fuzzy boundaries, the edge of chaos, improvisation, adaptation and transformation.</td>
</tr>
<tr>
<td>Nelson (2004)</td>
<td>Case Study (self-named) but more like action research or a self-study</td>
<td>13 university ESL students</td>
<td>Taught the class, collected student observations which were part of their regular portfolio assessment and conducted 3 formal semi-structured interviews with each student.</td>
<td>Reproduction = Yiping transferring her music skills and making them into writing skills. Recombination = Maria adding Power Point technology (from her computer sci background) into the usual stand and talk methods of this class. Replacement = students who were once uncomfortable with group work now embracing it.</td>
</tr>
<tr>
<td>Authors</td>
<td>Study Type</td>
<td>Sample</td>
<td>Method</td>
<td>Research Findings</td>
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<tr>
<td>Polite 1994</td>
<td>Case Study</td>
<td>115 AA males from 1 high school.</td>
<td>Followed this group from middle of sophomore year through 6 months after graduation. Follow up study 3 years later. Served as an assistant principal at the time. 600 hours of observation 242 semi-structured interviews with 65 students, 35 teachers/staff, and 35 parents Official and unofficial documents.</td>
<td>Butterfly effect: Early unrest in the 1970s, protests, etc. all snowballed to produce the present culture. Dissipating [his use of the word] structures: 1) uninvolved minority parents 2) peer pressure 3) teachers not demonstrating caring 4) lack of leadership in administration Strange attractor: student rejection of teachers perceived as insensitive Recursive symmetries: cites teachers’ consistent failures to effectively teach AA students.</td>
</tr>
<tr>
<td>Sinclair (2004)</td>
<td>Action Research</td>
<td>Her own algebra/geometry students; students from 2 schools using Java Sketchpad; Students in “Independent study project”</td>
<td>Observed her own classes and compared phenomena with Davis and Simmt’s criteria</td>
<td>Implies that the best learning happened in the class that most satisfied all of the conditions (Independent study project)</td>
</tr>
<tr>
<td>Authors</td>
<td>Study Type</td>
<td>Sample</td>
<td>Method</td>
<td>Research Findings</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------</td>
<td>--------------------------</td>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Zellermayer &amp; Margolin (2005)</td>
<td>Case Study / Self Study</td>
<td>15 student teacher supervisors.</td>
<td>Critical Incident Analysis</td>
<td>Change occurs in a special zone &quot;at the edge of chaos&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&quot;Paradox conflict and controversy as well as contradictory and unexpected interpretations of events, provide important opportunities for learning&quot; (p. 1300)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The tension between positive and negative feedback holds the group in the special zone &quot;at the edge of chaos&quot;</td>
</tr>
</tbody>
</table>
Boston College Consent Form

Informed Consent for Participation as a Participant in a study entitled “Complexity Theory in the Classroom: A Study of Three Learning Communities at Metropolitan Catholic High School.”

John P. Sullivan – Investigator
Student Assent Form
Date Created: August 4, 2007

Introduction
- You are being asked to be in a research study of group learning in high school classrooms.
- You were selected as a possible participant because you are a member of one of the classes being studied.
- We ask that you read this form and ask any questions that you may have before agreeing to be in the study.

Purpose of Study:
- The purpose of this study is to compare the way that learning happens in your class with a theory called “complexity theory.” It does not measure how good a student you are or how good a teacher your instructor is, but how well complexity theory explains what happens in your class.
- You will be one of twelve participants from three different classes, all at your school.

Description of Study Procedures:
- If you agree to be in this study, we would ask you to participate in one interview with Mr. Sullivan about how you perceive what is going on in your class. This interview will take less than one class period to complete, and can be completed before school, after school or during a free period, whatever is best for you.

Risks to Being in Study:
- The study has the following risks. First, though Mr. Sullivan will take measures to make sure that no one knows that you are participating in this research (see the confidentiality section below), it is possible that someone could figure out that you...
are participating. It is very unlikely that this would have any negative effect, but someone could hold it against you.

- In particular, none of your teachers will be told that you are participating. Should they find out that you are participating, there is a very small risk that they would use it against you, either in class, or in grading. This would require unethical behavior on their part. The teacher of the class being studied does not know which students are participating and has signed a form promising that, should he/she find out, it would not be used against you in any way, particularly in grading.

**Benefits of Being in Study:**
- Though there are no direct benefits to you for participating in this research, you will be contributing to a body of evidence that may improve the education of you or other students in the future.

**Payments:**
- Neither you, nor anyone else in the study will be paid for your participation.

**Costs:**
- There is no cost to you to participate in this research study.

**Confidentiality:**
- The records of this study will be kept private. In any sort of report Mr. Sullivan may publish, he will not include any information that will make it possible to identify you. Your real name will not be used. Research records will be kept in a locked file cabinet, and in password-protected computer files. Access to the records will be limited to the researcher; however, please note that the Institutional Review Board at Boston College, or Mr. Sullivan’s dissertation committee (Dr. McQuillan, Dr. Dudley-Marling and Dr. Patel-Stevens), also at Boston College, may review the research records.
- The audio recordings of your interviews will be kept in a locked file cabinet. They will be available only to Mr. Sullivan, his dissertation committee and the Institutional Review Board.
- Video recordings of your classes, which will be wide-angle shots of the entire class, not focusing on any one student, may be shown to you and other research participants during interviews, but will otherwise be available only to Mr. Sullivan, his dissertation committee and the Institutional Review Board.
- All notes, video and audio recordings will be destroyed no more than five years from the date of Mr. Sullivan’s dissertation defense.
- Mr. Sullivan will only violate these terms of this confidentiality agreement if he observes any illegal or unethical behavior, or if you make statements or other indications that you may be a danger to yourself or other people. In this case, he will notify only the appropriate authorities, and will not be responsible for otherwise
making any identifying information public, except as required by law, contract or research ethics.

Voluntary Participation/Withdrawal:
- Your participation is voluntary. If you choose not to participate, it will not affect your current or future relations with Boston College or [Metropolitan Catholic] High School.
- You are free to withdraw at any time, for whatever reason or for no reason at all. In interviews, you may choose not to answer any single question, or all questions.
- There is no penalty or loss of benefits for not taking part or for stopping your participation. In particular, it will not affect your grades in any class, or make you subject to any disciplinary action by anyone.

Contacts and Questions:
- The researcher conducting this study is Mr. John Sullivan. For questions or more information concerning this research you may contact him at 617-474-5131, or in the third year science office, located in A-308.
- If you believe you may have suffered a research related injury, contact Mr. Sullivan, or the school nurse who will give you further instructions.
- If you have any questions about your rights as a research participant, you may contact: Director, Office for Human Research Participant Protection, Boston College at (617) 552-4778, or irb@bc.edu

Copy of Consent Form:
- You will be given a copy of this form to keep for your records and future reference.

Statement of Consent:
- I have read (or have had read to me) the contents of this consent form and have been encouraged to ask questions. I have received answers to my questions. I give my consent to participate in this study. I have received (or will receive) a copy of this form.

Signatures/Dates
(delete those that do not apply to the protocol)

- Student Assent:
  Study Participant (Print Name): _______________________________
  Study Participant (Signature): ________________________________
  Witness/Auditor (Signature): ________________________________ Date ______

- Parental Permission/Consent:
Emergent Learning

Study Participant (Print Name) : _______________________________

Parent/Guardian (Print Name): _______________________________

Parent/Guardian (Signature): _______________________________ Date ________

Boston College Consent Form

Boston College Lynch School of Education
Informed Consent for Participation as a Participant in a study entitled “Complexity Theory in the Classroom: A Study of Three Learning Communities at Metropolitan Catholic High School.”

John P. Sullivan – Investigator

Consent Form

Date Created: August 4, 2007

Introduction
• You are being asked to be in a research study of group learning in high school classrooms.
• You were selected as a possible participant because you are the teacher of one of the classes being studied.
• Please read this form and ask any questions that you may have before agreeing to be in the study.

Purpose of Study:
• The purpose of this study is to compare the way that learning happens in your class with a theory called “complexity theory.” It does not measure how good a learner each of your students is or how good a teacher you are, but how well complexity theory explains what happens in your class.
• You will be one of twelve participants from three different classes, all at your school.

Description of Study Procedures:
• If you agree to be in this study, we would ask you to participate in one interview with John Sullivan about how you perceive what is going on in your class. This interview
will take less than one class period to complete, and can be completed before school, after school or during a free period, whatever is best for you. You will also be asked to participate in brief informal interviews as your schedule allows. For example, for a couple of minutes after class, you might be asked to comment on something that happened, or make arrangements for future observations.

**Risks to Being in Study:**
- The study has the following risks. First, though Mr. Sullivan will take measures to make sure that no one knows that you are participating in this research (see the confidentiality section below), it is possible that someone could figure out that you are participating. It is very unlikely that this would have any negative effect, but someone could hold it against you. In particular, no one at school, including any member of the administration, will be told that you are participating. Should they find out that you are participating, there is a very small risk that they would use it against you in the evaluation process. This would require unethical behavior on their part and [the principal] has promised, in writing, that data collected will not factor into your evaluation.

**Benefits of Being in This Study:**
- Though there are no direct benefits to you for participating in this research, you will be contributing to a body of evidence about how learning works that may improve the ability of teachers like you to optimize the education of students in the future.

**Payments:**
- Neither you, nor anyone else in the study will be paid for your participation.

**Costs:**
- There is no cost to you to participate in this research study.

**Confidentiality:**
- The records of this study will be kept private. In any sort of report Mr. Sullivan may publish, he will not include any information that will make it possible to identify you. Your real name will not be used. Research records will be kept in a locked file cabinet, and in password-protected computer files. Access to the records will be limited to the researcher; however, please note that the Institutional Review Board at Boston College, or Mr. Sullivan’s dissertation committee (Dr. McQuillan, Dr. Dudley-Marling and Dr. Patel-Stevens), also at Boston College, may review the research records.
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Video recordings of your classes, which will be wide-angle shots of the entire class, not focusing on any one student or the teacher, may be shown to you and other research participants during interviews, but will otherwise be available only to Mr. Sullivan, his dissertation committee and the Institutional Review Board.

All notes, video and audio recordings will be destroyed no more than five years from the date of Mr. Sullivan’s dissertation defense.

You will not be told which students will be interviewed. Should you find out, you must agree never to reveal this information to anyone else, or to treat such students differently in any way, particularly with respect to grading.

Mr. Sullivan will only violate these terms of this confidentiality agreement if he observes any illegal or unethical behavior, or if you make statements or other indications that you may be a danger to yourself or other people. In this case, he will notify only the appropriate authorities, and will not be responsible for otherwise making any identifying information public except as required by law, contract or research ethics.

Voluntary Participation/Withdrawal:

Your participation is voluntary. If you choose not to participate, it will not affect your current or future relations with Boston College or [Metropolitan Catholic] High School and will not affect your collegial relationship with Mr. Sullivan.

You are free to withdraw at any time, for whatever reason or for no reason at all. In interviews, you may choose not to answer any single question, or all questions.

There is no penalty or loss of benefits for not taking part or for stopping your participation. In particular, it will not affect your official evaluation, or make you subject to any disciplinary action by anyone.

Contacts and Questions:

The researcher conducting this study is Mr. John Sullivan. For questions or more information concerning this research you may contact him at 617-474-5131, or in the third year science office, located in A-308.

If you believe you may have suffered a research related injury, contact Mr. Sullivan, or the school nurse who will give you further instructions.

If you have any questions about your rights as a research participant, you may contact: Director, Office for Human Research Participant Protection, Boston College at (617) 552-4778, or irb@bc.edu

Copy of Consent Form:

You will be given a copy of this form to keep for your records and future reference.

Statement of Consent:
• I have read (or have had read to me) the contents of this consent form and have been encouraged to ask questions. I have received answers to my questions. I give my consent to participate in this study. I have received (or will receive) a copy of this form.

Signatures/Dates
(delete those that do not apply to the protocol)

• Faculty Consent:
  Study Participant (Print Name): _______________________________

  Study Participant (Signature) _________________________________

  Witness/Auditor (Signature): _________________________________ Date _____
APPENDIX D

*Interview Protocols*

These protocols are designed to be starting points, from which much more developed conversations will grow. The primary goal of the interviews will be to conduct member checks and provide triangulation, yielding multiple perspectives on the same critical incidents. Early questions, in addition to gathering demographic data, are designed to get participants talking, beginning a conversation that flows comfortably thereafter.

*Interview Protocol - Student*

Demographic Information

1. What town do you live in?
2. Are you comfortable telling me how your grades are – in general & in this class?
3. Could you describe your experience of this class in general? How is it different from other classes? How is it similar?
4. What is your favorite way to learn? Do you prefer tutoring, working in groups, lectures, labs?
5. [If the student hasn’t talked much about working in groups] How do you feel about working in groups? Are there times when you like it better than others, or think that it’s more appropriate than others?

Member Checking
6. Can you explain, in your own words, what you remember about [the day of the chosen incident]?

7. What did you know about [that day’s topic] before class began?

8. What do you think the class was designed to teach you on that day?

9. Did you learn anything that you don’t think was part of the original plan?

10. Would you say that you learned [some piece of knowledge brought up by the student (preferably), or suggested by the researcher]?

11. Do you remember where this information came from? For example, did you know it already? Did the teacher say it? Was it brought up by a member of the group? Was more than one person involved in coming up with this insight?

12. Is there anything else about this class, or the learning experience on that day, that you can think of that would help me understand your experience of it better?
Interview Protocol - Student

Demographic Information

1. How long have you been teaching at Metropolitan Catholic?
2. Do you have any experiences working in other schools? Where?
   When? For how long? How were they the same / different?
3. Could you describe your experience of this class in general? How is it different from other classes? How is it similar?
4. Tell me about how you think students learn in your class. What is your role? What is theirs? Do you think that students learn about different kinds of information in different ways?
5. [If the teacher hasn’t talked much about groups] How do you feel about student work groups? Are there times when you like it better than others, or think that it’s more appropriate than others?

Member Checking

6. Can you explain, in your own words, what you remember about [the day of the chosen incident]?
7. What did you know about [that day’s topic] before class began?
8. What were your goals for class that day?
9. Did you think that anything happened that was different from your plan? In particular, were there things that you felt like students learned that you weren’t expecting (including misconceptions)?
10. Would you say that students learned [some piece of knowledge brought up by the teacher (preferably), or suggested by the researcher]?

11. Do you remember where this information came from? For example, did a student know it already? Did you say it when you hadn’t planned to? Was it brought up by a student? Was more than one person involved in coming up with this insight?

12. Is there anything else about this class, or the learning experience on that day, that you can think of that would help me understand your experience of it better?
Appendix E

Geometry Worksheet

Geometry

Worksheet: Sections 9.1 – 9.4

9-1

Find the value of x in each parallelogram.

1. \[ 15 \]
   \[ x \]

2. \[ 26 \]
   \[ x - 4 \]

3. \[ 10 \]
   \[ 2x - 4 \]

4. \[ 4x - 10 \]
   \[ 3x - 2 \]

5. \[ AC = 24 \]

6. \[ 4x - 4 \]
   \[ 6x - 22 \]

7. \[ x = EC \]

8. \[ IK = 35 \]
   \[ 4x + 3 \]

Find the measures of the numbered angles for each parallelogram.

13. \[ 80^\circ \]

14. \[ 140^\circ \]
   \[ 1 \]
   \[ 2 \]

15. \[ 110^\circ \]
   \[ 3 \]

16. \[ 22^\circ \]
   \[ 45^\circ \]

17. \[ 60^\circ \]
   \[ 110^\circ \]

18. \[ 1 \]
   \[ 2 \]
   \[ 3 \]
   \[ 50^\circ \]

19. \[ 1 \]
   \[ 2 \]
   \[ 3 \]
   \[ 4 \]

20. \[ 1 \]
   \[ 2 \]
   \[ 3 \]
   \[ 4 \]
   \[ 50^\circ \]

Find the length of \( \overline{TI} \) in each parallelogram.

21. \[ T \]
    \[ 18 \]
    \[ E \]
    \[ 18 \]

22. \[ OR = \frac{1}{3}RO \]

23. \[ TR = 14, ME = 31 \]

24. \[ IE = 6, CT = 8 \]
State whether the information given about quadrilateral SMTP is sufficient to determine that it is a parallelogram.

1. \( \angle SPT = \angle SMT \)
2. \( \angle SPX = \angle TMX, \angle TPX = \angle SMX \)
3. \( SM = PT, SP = MT \)
4. \( SX = XT, SM = PT \)
5. \( PX = MX, SX = TX \)
6. \( SP = MT, SP \parallel MT \)

Determine the values of the variables for which the figure is a parallelogram.

7. \( \frac{4x + 20}{7y} \)
8. \( \frac{6x + 9}{x + 26} \)

Find the value of \( x \). Then tell whether the figure must be a parallelogram. Explain your answer.

9. \( \frac{5x - 4}{2x + 14} \)
10. \( \frac{3x - 2}{x + 4} \)
11. \( \frac{x + 27}{(3x - 25)} \)
12. \( \frac{(4x - 10)}{2x} \)

Based on the markings, decide if each figure is a parallelogram. Justify your answer.

13. \( \frac{\framebox{ }}{\framebox{ }} \)
14. \( \frac{\framebox{ }}{\framebox{ }} \)
15. \( \frac{\framebox{ }}{\framebox{ }} \)
16. \( \frac{\framebox{ }}{\framebox{ }} \)
17. \( \frac{\framebox{ }}{\framebox{ }} \)
18. \( \frac{\framebox{ }}{\framebox{ }} \)
19. \( \frac{\framebox{ }}{\framebox{ }} \)
20. \( \frac{\framebox{ }}{\framebox{ }} \)
Example 1

Find the measures of the numbered angles for each rhombus.

1. \[ \begin{array}{c}
1 \quad 2 \\
\end{array} \]
2. \[ \begin{array}{c}
1 \quad 2 \quad 3 \\
4 \\
\end{array} \]
3. \[ m\angle ABC = 44 \]
4. \[ \begin{array}{c}
1 \quad 2 \quad 3 \\
4 \\
\end{array} \]

Example 2

For each rhombus (a) find the measures of the numbered angles and then (b) find the area.

5. \[ \begin{array}{c}
\text{A} \quad 3 \text{ cm} \\
\text{B} \\
\end{array} \]
6. \[ \begin{array}{c}
\text{A} \quad 16 \text{ in.} \\
\text{B} \\
\end{array} \]
7. \[ \begin{array}{c}
\text{A} \quad 7 \text{ m} \\
\text{B} \\
\end{array} \]
8. \[ \begin{array}{c}
\text{A} \quad 20 \text{ cm} \\
\text{B} \\
\end{array} \]
9. \[ \begin{array}{c}
\text{A} \quad 6 \text{ m} \\
\text{B} \\
\end{array} \]
10. \[ \begin{array}{c}
\text{A} \quad 3 \text{ cm} \\
\text{B} \\
\end{array} \]

Example 3

For each parallelogram (a) choose the best name and then (b) find the value of the variable(s).

11. \[ \begin{array}{c}
\text{A} \quad \text{B} \\
\text{C} \\
\end{array} \]
12. \[ \begin{array}{c}
\text{A} \quad 20^\circ \\
\text{B} \\
\end{array} \]
13. \[ AC = 16, BD = 16 \]
14. \[ m\angle ABC = y \]
15. \[ \begin{array}{c}
\text{A} \quad \text{B} \\
\text{C} \\
\end{array} \]
16. \[ \begin{array}{c}
\text{A} \quad \text{B} \\
\text{C} \\
\end{array} \]
17. \[ (y - x)^2 \]
18. \[ \begin{array}{c}
\text{A} \quad \text{B} \\
\text{C} \\
\end{array} \]
Find the height of each isosceles trapezoid.

1. \( \frac{12}{13} \) \( \frac{13}{22} \)

2. \( \frac{19}{17} \) \( \frac{17}{35} \)

3. \( \frac{24}{15} \) \( \frac{15}{6} \)

4. \( \frac{24}{24} \) \( \frac{0}{16} \)

Find the measures of \( \angle 1 \) and \( \angle 2 \).

5. \( \frac{29^\circ}{2} \) \( \frac{2}{1} \)

6. \( \frac{68^\circ}{1} \) \( \frac{1}{2} \)

7. \( \frac{1}{1} \) \( \frac{1}{2} \)

8. \( \frac{121^\circ}{2} \) \( \frac{2}{1} \)

9. \( \frac{96^\circ}{2} \) \( \frac{2}{1} \)

10. \( \frac{1}{1} \) \( \frac{1}{101^\circ} \)

11. \( \frac{2}{1} \) \( \frac{1}{79^\circ} \)

12. \( \frac{1}{1} \) \( \frac{1}{56^\circ} \)

Find the values of the variables.

13. \( DF = 4x, EG = 2x + 16 \)

\[
\begin{align*}
D & \quad E \\
G & \quad F \\
\end{align*}
\]

14. \( 3x - 3 \)

\[
\begin{align*}
x - 1 & \quad x + 5 \\
3x & \\
\end{align*}
\]

15. \(\frac{(2x)}{(10x - 6)}\) \(\frac{(x)}{(3x)}\)

16. \( (5x - 1)^\circ \)

\[
\frac{(5x)}{(4x + 1)}^\circ
\]

17. \( (6x + 20)^\circ \)

\[
\frac{(6x)}{(4x)}^\circ
\]

18. \( 3x - 4 \)

\[
\frac{x + 5}{2x - 2}
\]

19. \( (5x - 8)^\circ \)

\[
\frac{(5x)}{(6x - 1)}^\circ
\]

\[
\frac{(5x - 3)}{(4x + 4)}^\circ
\]

20. \( LN = 3x, MO = y \)

\[
\begin{align*}
l & \quad m \\
\end{align*}
\]

21. \( TV = 4y, WU = 5x \)

\[
\begin{align*}
t & \quad u \\
\end{align*}
\]
Appendix F

Maps of *The Odyssey*
CHELSEA BRIDGE

- BILLY STRAYHORN

(BALLAD)

 Eb7    D9
 Eb7    Bb7    Eb7    Ab7

 Db0

 F#5    Bn
 Emaj7  G7
 F#5    F7
 Bn

 Amaj7  A7
 Dm7  Gm
 G7
 Db7  Cn  Bn  Gb7

 Eb7    D9
 Eb7    Bb7    Eb7    D9

 Eb7    Ab7    Db0

 FINE