Chapter 13
Assuming an Epistemology of Emergence: Classrooms as Complex Adaptive Systems

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Abstract This review of literature was conducted to identify practical implications of complex adaptive systems in the classroom. The article uses complexity thinking to analyze conditions for emergence. Emergence is understood in this context as a "teachable moment", and in order for students to capitalize on these many moments, the conditions for emergence must be set by the teacher and experienced by the students.

13.1 Introduction

I think cliff-diving is great. It may not be my passion, but it is a good time when the opportunity presents itself. And yes, it presented itself. First, consider the context. My teacher was not coaching me on the edge, nor were my friends—in fact, they simply yelled intelligibly. How did I learn this? Was I born with an innate ability to jump off high places? What a strange gift, but no, it was a moment of emergence. All my prior experiences from other situations came together to create a unique one—cliff-diving. Educationally speaking, it resembled a "teachable moment". Fortunately, I possessed the agency to capitalize on the moment and execute the jump. The intense learning occurred at the precise moment I shifted my weight, bent my knees, prepared my mind, cast away my fears, swung my arms, and pushed off the rocky edge. Retrospectively, it was a complex process, especially having never done it before. Although the first jump was simply a matter of survival, subsequent jumps used related information to increase my proficiency. A nonlinear, dynamic process seemed to emerge from nothing—a new world was revealed. It is this reason, and the intense learning that occurs in the "teachable moment" that I have assumed an "emergentist" epistemology. I believe that "knowledge emerges from our transactions with our environment and feeds back into this same environment, such that our environment becomes increasingly meaningful for us (p. 223, [14])."

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13.2 The Purpose

It is nearly impossible to predict and control educational outcomes. Learning is dependent on teaching, but what the students learn is unpredictable [4]. Teachers cannot delineate individual causes of the student's learning [3]. Classrooms are unpredictable because of their ecological multidimensionality, simultaneity [7], and nonlinear dynamics. Linear models fail to capture the complexity of learning communities. Educational researchers are now utilizing complexity thinking when observing classrooms as complex adaptive systems [4]. So, how does knowledge of complex adaptive systems inform teacher practice? Answering this question is important because learning environments can suffer from reductionist beliefs resulting in linear teaching models and frameworks. Teachers need to be aware of the underlying nonlinear dynamics in the seemingly chaotic classroom [18]. In fact, teachers should strive to inhabit the zone between order and chaos—this is where the intense learning occurs [1, 13]. Teachers should provide conditions for emergence, and prepare their students to capitalize on it.

This review of literature provides a conceptual framework for understanding the role of complexity in education, and how teaching should be understood as a complex adaptive system. The review will begin by discussing complexity thinking. The discussion will lead to the concept of Complex Adaptive Systems (CAS). Next, the CAS is related to the classroom. After building the foundation, the impact on educational research is analyzed. Finally, implications for teachers are explored. The primary purpose of this paper is to move complexity and education from the theoretical to the practical.

13.3 Complexity Thinking

The term complexity is often followed by the words science, theory, or thinking. For the purpose of this paper, complexity thinking is used. Scholars who ascribe to this thinking will be referred to as "complexivists." The purpose of complexity thinking is not to establish fact (science), nor explain what seems to be (theory), but to establish practical means for thinking about what already is, and what it might be. Complexity thinking can be used heuristically, as tools for interpretation, problem solving, and, ultimately, guide action [5].

Complexity is a lens with which to examine nonlinear, dynamical, emergent systems, or CASs. CASs are characterized by complex interactions of adaptive agents. Complexity thinking is particularly useful when explaining social groups. The dynamics of a group are similar to (and work with) the intrapersonal dynamics of individuals which are both subject to the complex dynamical systems of external influences. Thus, it makes complexity a necessary lens when observing social constructs.

Nonlinear systems have a fundamental order, but often appear to be chaotic [15]. These systems can only be determined from one point to another. This

seems to be the only tangible aspect of complexity. A current state forms the foundation for next state of the system. When studying one point in time, it is rather straightforward. However, the direction in which the system will take is still unpredictable. Essentially, nonlinear systems undergo "successive iterations" that feed back into the system.

Emergence is also referred to as self-organization [14]. Emergence is the ability to organize into existence. There is no leader, or creator [5]. Although systems seem to appear from thin-air, the new form is actually the result of the system organizing its sufficient disorganization [8]. Thus, the system remains on the edge of chaos—never completely stabilizing, but never reaching disintegration.

The concept of emergence is particularly important in this review. Emergence in the classroom resembles the "teachable moment", or the "Ah-hah" experience [4]. This is when knowledge organizes itself into a unique understanding. Teachers covet these moments, and examining emergence might help bridge the theoretical to the practical.

Complex systems cannot be represented by anything less complex. According to complexity science, systems cannot be compressed or reduced. Compression results in losing parts of the system [5, 12, 14]. The reductionist method of complexity, however, is a matter of debate among complexity scientists. Complexity thinking recognizes the limitations of the human mind, and allows for some reduction when studying complex systems. The shift is primarily caused by the need to use knowledge of complexity in a pragmatic way. Complete understanding of a system that no human can analyze requires reduction. Complexity thinking lends itself practically in order to promote appropriate actions in complex systems [3, 5, 4, 12].

Complexity thinking moves beyond the epistemologies of structuralists and post-structuralists [4]. Structuralists are primarily concerned with how the mind creates knowledge through relations [2]. Essentially, knowledge does not have to relate to the real world, but is created in the mind based on countless influences. Structuralists focused on the cognitive organization of knowledge. The post-structuralists hold similar beliefs, but are interested in culture and power's influence in the structure of learning. They agree that learning cannot be decontextualized, and power relationships in culture and language are no exception [5]. Complexity thinking goes beyond explanation, and contends to turn the nebulous of complexity into practical implications for interested parties—in this case, teachers. So, complexity thinking is used reflexively with CASs. This is important because this author will use complexity thinking to focus on functionalism and pragmatism [14].

13.4 Complex Adaptive Systems

CASs differ from complex systems in that CASs evolve, aggregate, and anticipate. CASs evolve constantly in a competitive fashion to become more fit. The system works in a realm that is ever-changing [10]. It is in a constant state of "becoming"

without ever reaching an ultimate goal [14]. However, the CAS becomes better fit for the temporal environment [13]. Holland [10] uses the concept of antibodies to explore this evolution as adaptation. Antibodies cannot ascribe to a set list of antagonists, but work together to fight a constant barrage of new and different attacks. Therefore, to keep a human system healthy, the immune system must constantly evolve to win ongoing battles of varying circumstances. An immune system's inability to adapt would result in the destruction of the human. This is where the competitive evolutionary concept is essential in CASs.

Aggregation is the ability to categorize separate systems. CASs, although not without overlap, attempt to delineate behaviors within. The rules for aggregation are also always developing and changing. Thus understanding the concept linearly can provide a model for understanding the truly nonlinear process. Though the system categorizes, the categories adapt with evolution [10].

The third characteristic of the CAS is anticipation. This ability is the least understood of the three. Of course, it makes sense because of the discussion earlier regarding the inability to predict outcomes in CASs. However, the system itself can consistently anticipate outcomes [10]. This author, heretofore, believes the system can only anticipate immediate outcomes. The belief stems from knowing CASs are endless, and only exist to improve the temporal fitness [14].

Within the CAS, simultaneity occurs. Many parts are active at once. Also, there are many aspects at work in the system, that is, they are multidimensional. All of these factors in this section contribute to the unpredictability of these systems.

The CAS is often understood through the use of metaphors. One such metaphor is "The Butterfly Effect." This is in direct opposition to Newton's belief that small causes result in small effects as well as large causes render large effects. The Butterfly Effect illustrates how effects cannot be predicted by the magnitude of the cause. The wind emitted from a butterfly's wing in Korea could possibly cause a tornado in Texas {{Robinson 1993}}.

13.5 The Classroom as a Complex Adaptive System

The classroom is a CAS. Doyle [7] conducted an ethnographic ecological analysis of secondary classrooms in which university supervisors observed ten groups of four to six student teachers and their classrooms. The study analyzed instructional episodes and student/teacher interactions. The student teacher, cooperating teacher, and the university supervisor completed the necessary triangulation of qualitative data. The researcher noted the impossibility of representing all the descriptive data, but noted the most salient characteristics. The most salient features of the interactions and classroom phenomena were simultaneity, multidimensionality, and unpredictability.

Reactions (both students and teacher) to the three salient characteristics observed, like a CAS, could not be determined before the occurrence. One thing is certain: after each interaction, the classroom collective was never the same again. What was before evolved into something new, which will then immediately and inde-

terminately evolve again. The classroom is, also like a CAS, always "becoming" and never "arriving." Linearly, one would have assumed some sort of arrival, but truly, classrooms never "get there", they only become increasingly fit for emerging situations [10].

The brain is a complex adaptive system [1]. Essentially, then, there are complex adaptive systems within the complex adaptive classroom. This phenomenon is understood through fractal geometry and the concept of self-similarity. Each level is similar to the underlying level [5]. A study on academic motivation will be used to illustrate the complexity of individual students.

Dowson et al. [6] conducted a large scale, longitudinal, mixed method study of variables influencing student academic motivation. The experimental group consisted of 107 high school seniors and eight teachers from a boy's school in Sydney, Australia. The control was approximately 800 students from previous cohorts. Results of the study indicated that motivation is nonlinear. One might expect student motivation to continue to rise throughout the year, and of course, this would be optimal. However, motivation at particular intervals did not reflect linear growth/decline. Interviews, surveys, observations, and academic records were used to determine reasons for the fluctuating motivation.

The researchers found a constant interplay between personal, interpersonal, institutional, teacher motivation, and other various factors influencing student motivation [6]. They conclude that one cannot separate the ecological factors from the intrapersonal when assessing student motivation. The system must be studied from a holistic perspective. No single variable can be entered into a cause and effect equation to determine an outcome. Instead, classrooms, and the students within, reflect nonlinearity and adaptation (for better or for worse).

13.6 Implications for Educational Research

The lack of empirical research on this topic made this review difficult. Only two research studies were found to examine the interpersonal perspective of CASs. The remaining three empirical studies focused on cognitive processes of reading as a CAS. There is an obvious need for further inquiry. However, there was no shortage of theoretical papers. Many authors overlapped in their beliefs, regardless of differing vocabulary. Most of the researchers agreed that education cannot be viewed in a linear model; the learning environment is too complex and nonlinear.

How can research focus on the initial conditions of emergence? Teachers are very adept at dealing with nonlinearity. In fact, some researchers claim teachers are already experts in the field, and should assume leadership roles promoting CASs [13]. Would this experiential knowledge contribute to reading research methods? Teachers possess a tacit understanding of CASs because of the daily art/science of teaching. Whether they know it or not, they are completely immersed in complexity.

The "teachable moment" is highly desirable, but almost indescribable [5]. Assuming the epistemology of emergence will help researchers focus on the initial

conditions present immediately prior to the teachable moment [14]. It is this author's goal to understand this phenomenon.

What is the teachable moment? It must first be easily identifiable. It occurs in transitional stage between order and chaos. Perfectly disorganized information reorganizes to create a new thought [8]. This, naturally, might be difficult to see with the naked eye, or even a highly trained one. Though some teachable moments are recognized, it is this author's contention that many go unnoticed. This may be the result of a threatening environment or the lack of an established collective. It is unknown whether a lack of, or inability to recognize, teachable moments is the case. However, the problem of identifying the moment still exists. One must understand either the conditions, or the identification of emergence to study it successfully. The previous seems more viable.

Knowledge emerges from every transaction with the 'the world' [14]. If this is true, teachable moments are everywhere, and initiated by everything. Researchers may have to identify a classroom with a strong collective and decentralized teacher, observe the classroom, and conduct a path analysis. Of course, the generalizability would be zero assuming that learning is particular to a specific collective engaging in a unique construction of knowledge. The existing conditions of the collective classroom could be analyzed against classrooms with centralized teachers. From that, scale scores for level and predictability of learning can be compared.

Although conditions of emergence are not completely clear, one thing is—these conditions cannot be examined linearly. This might be the reason for the absent of clarity in emergence. Despite complexivists' warnings, empirical research is still being conducted linearly [15]. A need for extensive ethnographic and naturalist research paired with discourse and path analysis is apparent.

13.7 Impact on Teacher Practice

Human behavior is inherently undeterministic [3], and learning is a human behavior. Learning is not determined by teaching. Nevertheless, learning is dependent on teaching [4, 14]. Of course, this statement is assuming that anyone, thing, or experience can act as a teacher. The question in mind may resemble, "Why teach?" However, a better question might be, "How should we teach?" Alternatively, a more specific question would be, "What is the role of the teacher?"

In complexity thinking, the role of the teacher is to create opportunities for emergence. The teacher is required to assume a decentralized role in learning. The complex adaptive system centers on the most abundant flow of information. This, historically, is the teacher. However, if the teacher assumes the central role, the student is limited by the knowledge of the teacher. Likewise, if any one student gains more power, the group is limited by their level of knowledge. If the classroom collective is characterized by emergence with a primary goal of exploring what is not-yet-imaginable, then the teacher's control should be limited. Otherwise, the teacher acts as an impediment to optimal learning. The teacher, of course, should not

step back completely and rely on learning to happen by chance, but should carefully control the container of the complex adaptive system [8]. Unfortunately, for the teacher, the container is also part of the CAS; therefore, the boundary is constantly shifting. This boundary, like the rest of system, should be allowed to evolve.

Teaching reading is a complex process. Roehler [16] studied teachers who embrace these complexities. His subjects included a first grade teacher and 24 students, a third grade teacher and 27 students, and a sixth grade teacher and 24 students. As Davis and Sumara [4] suggest the quality of teaching was based on student's learning, not on teaching methods. However, the teacher beliefs and understanding were particularly important in the study. Once the study was complete, researchers conducted a correlational analysis of teacher beliefs and students' strategic reading [16].

The researchers interviewed the three teachers (pre-, mid-, and post-year) to determine the degree in which they embraced the complexities of reading. Researchers also tested the students using a modified GORP test adapted from the Qualitative Reading Inventory (pre-, mid-, and post-year). Teacher A demonstrated the highest understanding of reading's complexities. Similarly, the students' strategic reading abilities increased the most. Teacher B was described as reducing the complexities of reading. The students demonstrated a lower understanding of strategic reading than students of Teacher A. Lastly, Teacher C decreased in understanding of reading's complexities, and the students made little or no growth in the reading categories assessed [16].

The previous study correlates teacher understanding of complexities of reading with higher strategic reading among students (Roehler & Michigan State Univ, East Lansing Inst for Research on Teaching, 1991). In this study, Teacher A was also a learner. It would have been interesting to study how the increased knowledge of complexity affected the role of the teacher. Did Teacher A create more opportunities for emergence in the literacy classroom?

Sumara and Davis (2006) argue that emergence is much like the desirable "teachable moment". The teachable moment is not a product of the teacher. Nor is it a manifestation from a single student or idea. In fact, the teachable moment does not even have to be addressed by the teacher. Other students or objects can instigate learning. Teachable moments, or emergence, are the direct result of creating a classroom collective—a place where student learning occurs in relation to other students, ideas, and experiences. Arguably, this is the place where optimal learning occurs. It is sometimes referred to as "the edge of chaos." On the edge of chaos, the system must self-organize to avoid disintegration. This is when something new emerges. This is the key to learning and teaching. Of course, no one obtains the key without a price. The price is decentralizing the role of the teacher. It can be hard to give up such power. Losing control in a classroom is like executing a first cliff-diving back flip. The height is merely estimated; the depth of the water is unclear. Yet both affect the necessary speed of rotation. The power required for lift-off is based on quasi-related experiences. All of which do not precisely predict the real outcome. Rest assured, one can always execute multiple attempts. Fortunately, the second attempt is based directly on experience. With each jump, new information is

reorganized. Remember, there is no such thing as a perfect back flip, but some are more aesthetically pleasing. The cliff and surrounding factors, created a situation for emergence. Although the back-flipper had no formal education in this area, the jump was a success, and got progressively better with increased experience.

The indication that learning occurs with or without a certified teacher, prompts researchers to question teaching methods. Throughout this research, the author has assumed an epistemology of emergence, that is, classroom ecology that promotes maximum opportunities for emergence encourages learning [4]. Most educators would agree that learning is essential in classrooms. Mason [12] describes learning as "a process of emergence and co-evolution of the individual, the social group and the wider society (p. 25)."

Learning to read is not easy. Reading, itself, is complex and nonlinear [9]. Teaching reading is also complex. Teachers need to create classroom collectives that co-evolve adaptively toward something greater (or different) than before. The goal is to create strategic lifelong readers. When looking at a young reader, it may be difficult to see them as such. In fact, it is a clear representation of what is not-yet-imaginable [4]. Obviously one mind cannot conjure incalculable outcomes. Therefore, the students, as well as the teacher, need to depend on the classroom as a CAS. Specifically, information must flow freely in the network collective. Theoretically, it sounds perfect. The teacher has to create good lines of communication—easier said than done.

Students will not speak up if they believe it does not matter. Each student needs a sense of agency. They must view themselves an important factor in literacy learning. For a student to be agentive, they must acquire a literate identity. This requires action from the classroom collective, including a teacher with knowledge on the subject. Essentially, the first identity that needs to change is the teacher's. Building a collective of readers and authors begins with the teacher releasing control to the students (decentralized role of the teacher). Eliminate the standard authoritarian-type relationship to prepare the room for serious identity overhauls. Balancing teacher and student power is more conducive to a learning organization. As the concept "we" breaks through the power differential in classrooms, students begin to take responsibility for learning. Not only are they responsible, but students become the key agents in the construction of knowledge [11]. Thus, it creates more opportunities for emergence [14]. Note, the teacher provides this opportunity; it is not orchestrated or managed.

Sometimes a simple twist of a common phrase makes all the difference. A student's role is often the teacher-pleaser; however, this does not conjure the most independent and intrinsically motivated learner. These students long for the phrase "I'm so proud of you" to spring from their teacher's lips. What if, for example, the phrase was slightly altered in a way that actually builds pride in the students rather than the teacher? "You should be proud of yourself (p. 25)" does just that; it effectively gives permission for the student to accomplish tasks for him. It eliminates teacher-pleaser mentalities and instills internal motivation [11].

Now that the students are not simply "doing school", a new identity must replace "student". This slot can be filled with whatever is necessary to collectively complete

a task. For example, when writing, "author" is used; when reading, "reader"; if students are conducting research, replace with "researcher". Affixing of labels, of course, will not eliminate the need for instruction; students will need guidance as authors, readers, and researchers. In the case of creating a literacy classroom collective, equal weight is given to student input [11].

Now that students have acquired a literate identity, they can become agentive in the classroom. Johnston [11], eerily similar to research in CASs, describes agency as "the perception that the environment is responsive to our actions (p. 29)." In fact, students, through CAS, can understand how massively correct they are once assuming agency. This is a great example of The Butterfly Effect [15]. The student, unknowingly, has changed the dynamic of the classroom and learning forever. The student's contribution was unfathomable. Amazingly, it is the first step in taking literacy learning to places unimagined. The teacher alone could not create this trajectory; therefore, building agency in students is imperative. Teachers must insist on students adopting agency. The teacher can facilitate agentive thinking by helping students realize they are responsible for their learning. The students actively plan, reflect, and modify literate experiences [11]. Sharing these experiences will invite the collective to learn, process, and assimilate them.

Teachers are lucky that learning is a CAS. It helps define the teacher's role. The classroom is a direct response to interactions of the students within. The teacher is responsible for creating the responsive environment desperately needed for learning. Teachers need to create safe environments as threat often hinders learning. Conversely, a challenging classroom enhances learning [1]. Once safe, students are free to develop their literate identity and assume agency. At this point, the collective is formed. The ride begins. The destination is unknown, but it is supposed to be. If it were known, a teacher could simply state it, or show it. To learn, knowledge must emerge from the minds of the collective. The students create knowledge in a way that has never been done before. The students did not discover it. The teacher did not uncover it. The collective learning community created it.

The collective's power cannot be measured by the sum of its parts. Once it comes together, no one can describe it conventionally. Of course, the teacher has a responsibility in this—they dissipate into the collective becoming just another node in the CAS, and join the journey to the undreamed of learning on the edge of chaos—an endless source for what is not-yet-imagined.

Teachers should focus on the conditions of emergence, and build a classroom around it. Although, in the past, education has representational epistemology, where learning is decontextualized, but represented as "real life" in the classroom, a movement towards an 'emergentists' epistemology acknowledges the boundaries of classroom, but uses its contents to extend learning to unknown destinations. The learner and 'the world' are in the same complex system [14].

13.8 Conclusion

Outcomes in learning are unpredictable [4]. I hope that this claim is no longer threatening. In fact, it should act as relief, for learning is about constructing the unimaginable. Teaching is not about ultimate control. It is about affecting learners with the least possible influence, and most positive outcomes. These outcomes, of course, are left to the devices of the classroom collective. To completely understand and buy into such a claim, one must shift beyond the umbrella of post-structuralism, and assume an 'emergentist' epistemology. My students and I are a part of the greater CAS. Through schooling, students create meaning that helps us understand 'the world' a little more. Even though the world never reveals itself completely, students continue to re-negotiate prior conceptions [14]. This act of re-negotiations happens through interaction in everything they do. A teacher's ultimate control is detrimental in the construction of knowledge. Step back; let the collective experiences, and innate need to create order drive learning [17]. Do not let cliff-diving be a student's only opportunity for emergence.

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