論　文

Learning and Complex Adaptive Systems Part 2

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要　約

本論文は，複雑性と複雑適応系の科学，およびそのような科学が人間の学習についての理解にもたらし得る知見について論じる。人間の思考を複雑適応系と見なす可能性について検討するとともに，そこから学校教育の学習環境の設計に対して得られる含意を提示する。筆者は，生徒が事故の学習地平を形成するべく積極的な行動をとることができるよう，「車輪の再発明」を行わせることの重要性について論じる。

Abstract

This paper discusses the science of complexity and complex adaptive systems and how such science might inform the understanding of human learning. The possibility of viewing human thinking as a complex adaptive system is explored and implications for designing formal learning environments are suggested. The author argues for the importance of allowing students to “reinvent the wheel” in order to take an active part in sculpting their individual learning landscapes.

Part 2: The Learning Landscape

Introduction to the Learning Landscape

> There are always multiple layers in a landscape. That's why revisiting a landscape is never boring. Every time we return, we see it in a different light. We normally see an intermingling of different aspects of multiple sub-landscapes when we appreciate the beauty of the whole. (Visser, Landscaping the Learning Environment to Create a Home for the Complex Mind, 2001)

Visser writes about the "learning landscape" as a way of visualizing the external contexts within which learning takes place. Kelso maps the interior learning landscape. The concept of the learning landscape fits nicely with the research on complexity and learning, as well as providing a visual metaphor for the next portion of this discussion.

The previous discussion of complex adaptive systems and brain functioning lends itself to a view of learning as an active, evolving process rather than as a product. In addition, it suggests that the learning process is a nonlinear one. Simple ideas of cause and effect cannot adequately describe the learning process. The ever-changing nature of the learning process makes a definition of learning in terms of products unworkable. The very best one can hope for by naming products is a snapshot of a moment, recognizing that, like all snapshots, the moment it describes is irretrievably transformed by time. Thus, the snapshot can never provide a definitive description.

Not only does this perspective require one to view learning as a process which is inextricable from the system of which it is a part, it requires a recognition of each human as a unique entity within whom there is an irreducible and irreproducible context in which learning is taking place. The context is irreproducible in any other human, as well as in that same human at a different moment in time. Learning is not the process of capturing a moment, but a process integral to creating the moment. This is an important distinction, and one which merits consideration in any discussion of the design of formal learning environments.

Biologue

The idea of continuous dialogue fits well with what has been discussed about complex adaptive systems as well as autopoietic unities. In an attempt to capture an even more dynamic notion—an image of many, many dialogues occurring simultaneously, at many levels of living interactions, a new term is proposed: *biologue*.

Biologue encompasses the concept of interactions and transformations occurring simultaneously at all levels (in this case, the term levels denoting differences of scale and organization) of complex biosystems. In fact, as a starting point, biologue may be described in precisely these terms. *Biologue is the continual interaction and transformation occurring at all levels of a complex biosystem*.

Learning itself can be seen in terms of this biologue. One possibility is to describe learning as the biologue of a self-organizing complex biosystem through which transformation the system creates itself. Seen in this way, every agent of a complex biological system is in a continual process of transformation that is essential to the existence of the system. There is a sense of unceasing activity through which a world is created, after the ideas of Maturana and Varela (26). This description also conveys the relevance of context, both physical and temporal, within which learning takes place. And finally, inherent in this perspective is the underlying notion of the unique history of the system, as the future of the system is created within the context of its physical and temporal present, the present constructed from the system's physical and temporal past.

Curiosity and Learning

While learning as a process may be fairly easy for the reader to go along with, learning as a nonlinear process may be a bit more difficult. Learning as a linear activity is deeply embedded in our language and philosophies.

For example, Shulman says "learning is basically an interplay of two challenging processes—getting knowledge that is inside to move out, and getting knowledge that is outside to move in" (1999, p. ?). Shulman further explains "these two processes—the inside-out and the outside-in movements of knowledge—alternate almost endlessly" (?). From the point of view of complex systems, this linear alternation grossly oversimplifies the learning process. Here the view is of knowledge as a noun, a static representation in the mind, and the process of learning is seen as an attempt to move discrete units of knowledge back and forth between the learner and … what? or whom?

To use the word *knowledge* in reference to learning is to conjure an image that belies the intricate dynamics of which current brain research suggests knowledge is comprised. Maybe it is time to reconsider our conception of that word, maybe even replace it with a new concept, the verb: *knowing*—to signify the verb *know* in the present progressive tense. It is a simple change that conveys a dramatic change of perspective.

Visser, whose work is steeped in an understanding of complex dynamics, defines human learning as "the disposition of human beings, and of the social entities to which they pertain, to engage in continuous dialogue with the human, social, biological and physical environment, so as to generate intelligent behavior to interact constructively with change" (Visser, Integrity, Completeness and Comprehensiveness of the Learning Environment: Meeting the Basic Learning Needs of All Throughout Life, 2001, p. 453). Thus, according to Visser, learning is more a disposition of mind than an activity—more a readiness to act than a particular action. For our discussion, Visser's definition might be productively applied to the term *curiosity* .

Visser has further suggested that this disposition "is based on openness of mind and willingness to interact, i.e. on the readiness to give and in the process receive" (Visser, The Conditions of Learning in the World of the Twenty-First Century, pp. 8–9). This captures beautifully the notion of curiosity.

If one looks simply at the idea of willingness and readiness to interact, it can be said that this definition might apply to complex systems in general. In fact, this precursor to learning, this learning potential, may be said to be fundamental to complex system dynamics.

This view of curiosity, like the view of learning previously discussed, may have consciousness as a component, but consciousness is not necessarily required. It is more of a biological approach to curiosity. Webster's defines curiosity as, "a desire to learn" (Guralnik, 1979, p. 153). The desire need not be a conscious one, but rather is an innate disposition (to use Visser's term) toward learning.

The reader might question the value in viewing curiosity and learning from this biological perspective when considering the design of formal learning environments. The value lies in approaching an educational environment with the assumption that every participant is naturally predisposed toward learning and in fact, is learning all the time. To design with this assumption in mind is to see the designer's (and the teacher's) role as more of a facilitator than as one who is to impart knowledge packets that must somehow be "gotten into" the learner. When we encourage an innate disposition to learn, we are activating a biological imperative.

Even if one can accept that every participant is learning, there may be a discrepancy between the learning taking place and the learning intended by the teacher, curriculum designer, parents, facilitator or society. The focus in the educational system is often on what is not being learned, rather than what is being learned. The situation is further complicated by the fact that even learners themselves often cannot identify, are often not even aware of, vast tracts of their own learning landscapes.

Then, what is the point of talking about curiosity and learning without consciousness? First of all, simply assuming that everyone is learning all the time might move the focus within the educational system from lack to abundance. A focus on the abundance of learning might generate a more encouraging environment for all concerned. Secondly, the admission that no one can possibly fathom the entire learning landscape and its continual transformation might stimulate questions about how learning is or should be assessed. Thirdly, and possibly most importantly, such an approach might encourage greater mindfulness regarding how and what manifestations of learning are valued.

Consciousness and Learning

This paper has argued for a view of learning as a process that is fundamental to living and inseparable from it. Now the focus is going to move from this general understanding toward some aspects of learning that are of particular concern to those involved in formal learning environments. The first of these topics is the role of consciousness in learning.

A theory of consciousness is well beyond the scope of this paper. It will not be necessary here to determine the origin or nature of consciousness, or to define consciousness in specific terms. A simple definition (taken from Webster's New World Dictionary) of consciousness as "awareness" will suffice(Guralnik, 1979, pp. 132–133). This conventional use of the term consciousness will be entirely adequate for the discussion to follow.

From the discussion so far it could be said that if a complex adaptive system exists, then it is engaged in biologues in which learning is taking place. Similarly, if learning is not taking place then the system ceases to exist. Therefore, it is safe to assume that in every living human, learning is continuously taking place. If an individual human is a complex adaptive system comprised of many other complex adaptive systems, it can also be said that biologues are going on simultaneously at many different scales.

For the sake of discussion, I'd like to suggest a somewhat arbitrary division of these many biologues into three categories with regard to consciousness: 1) those of which one is unaware, 2) those of which one has the potential to be aware, and 3) those of which one is aware. The first category—biologues of which one is never aware under ordinary circumstances—would include those taking place at the cellular level, for example. With the possible exception of certain laboratory situations, a human individual is entirely unaware of the firing of neurons in the central nervous system and the exchange of gases involved in respiration. If one can accept that these cellular systems are indeed complex adaptive systems, then learning at this level is certainly taking place. While such learning is of great importance to the survival of an individual, it is not generally considered a subject of consciousness. This is not to say that consciousness cannot affect these processes, only that the processes themselves, at a cellular level, are not subject to conscious awareness. For ease of discussion, this level of learning will be referred to as nonconscious learning.

Research also suggests that unconscious learning is taking place during the myriad interactions with one's social and physical environments as one goes about the business of daily living. For example, one may feel uncomfortable in meeting a particular person for the first time, and without realizing it, step back a pace or two from that person. This bias may likely be the result of unconscious learning.

Unconscious learning and responses also have great value for survival. For example, a friend once described a situation in which she was waiting at the curb for a bus. She was reading while she waited, her conscious attention focused on the book. Suddenly she realized that she had jumped back as a car had come up over the curb in the place where she had been standing a moment before. Her body responded to the threat before the danger had had a chance to register in her consciousness. She only realized what had happened after the event. LeDoux discusses the fact that reactions such as this bypass the cortex, thus they are not subject to conscious interpretation while they are occurring(1998, p. 163). This bypass buys the human the tiny bit of extra time that may mean the difference between life and death. Unconscious learning is a powerful force in the human experience and the implications for formal learning environments are intriguing. We will explore this idea further in the next section.

The second category—biologues of which one has the potential to be aware—might include activities of the systems mentioned above, but occurring on a larger scale. For example, breathing is an activity of the respiratory system of which one is generally unaware. However, it is easy to raise breathing to the level of awareness, and even to change breathing patterns through intention. Other types of biologues in this category might include habitual or routine interactions, skills one has learned and at which one is proficient, concepts which are well understood, and conscious beliefs. During these types of biologues, adjustments and adaptations may be taking place without one's active focus or awareness. For example, it is a common experience to have driven a route traversed many times before with no conscious recollection of the journey.

The third proposed category includes biologues of which one is aware, such as whatever thoughts are being attended to and focused interactions with elements of one's internal and/or external environment which are not routine or habitual. It will be clear to the reader that there is not specific division between categories two and three of this description, as activities in category two have the potential to move into category three, and activities in category three may pass into category two.

The main point of this discussion of learning and different degrees of consciousness is to illustrate the fact that, while schooling focuses almost entirely on conscious learning, conscious learning constitutes only a small fraction of all the learning taking place in an individual at any particular moment. At the same time, the learning going on at all levels, conscious, potentially conscious, and nonconscious, comprises the entire individual context in which new learning is taking place. This raises the question of whether one can take into account a learning landscape the totality of which is unknowable.

This paper argues that the impossibility of knowing the totality of the learning landscape is not as important as understanding that such a vast, ever-changing landscape exists. In addition, research into cognitive processes is revealing parts of the learning landscape which have previously been entirely hidden from view. Our decisions about how to design and implement structured learning environments can benefit from these new perspectives.

Furthermore, this perspective suggests questions about the strict focus on conscious learning in formal learning environments. As Dewey said, " Children doubtless go to school to learn, but it has yet to be proved that learning occurs most adequately when it is made a separate conscious business" (Dewey, Democracy and Education, 1919)

Unconscious Learning

While the main focus in structured learning environments has typically been on conscious learning, unconscious learning might also be put to good use in the classroom.

In fact, ignoring the major influence of unconscious learning may have a detrimental effect on the conscious learning that is taking place.

In contrast to the three levels of awareness suggested above, researchers in cognitive psychology have developed several dual-processing theories of cognition (Kaufmanpp. 445–447; Kahneman, 2011, pp. 19–30). Although they do not agree on the particulars, in general these theories posit Type 1 processes, which are fast and typically occur beyond the reach of conscious awareness, and Type 2 processes, which are slower and more deliberative, and which are the domain of the conscious mind. Type 1 processes, Kaufman writes, "are heavily influenced by context, biology, and past experience; and aid humans in mapping and assimilating newly acquired stimuli into preexisting knowledge structures" (445). These Type 1 processes are continuously working, sometimes to our benefit, and sometimes to our detriment. They are expert at finding patterns and, in the absence of multiple instances to draw conclusions from, will generalize from a single experience(Hill, Lewicki, Czyzewska, & Boss, 1989, p. 385). This explains, to a certain extent, how we can express biases that are in direct conflict with our consciously held beliefs (Hill, Lewicki, Czyzewska, & Boss, 1989, p. 386; Kahneman, 2011, pp. 79–88).

But the speed of Type 1 processes and their accuracy without the intervention of Type 2 consciousness makes it possible to learn highly complex information that might otherwise be unavailable. In many experiments, Lewicki and his colleagues have demonstrated the efficiency of nonconscious learning and the inability of the conscious mind to identify or articulate the learning that has occurred(Lewicki, Hill, & Czyzewska, 1992, pp. 797–798). The conscious mind, however, benefits from the learning that has taken place at the unconscious level.

Although Lewicki's research suggests that conscious beliefs and goals do not seem to influence Type 1 processes(1992, pp. 800–801), some researchers believe that Type 1 processes may be affected by nonconscious goals (Eitam, Hassin, & Schul, 2008, pp. 261, 266). Eitam, Hassin, and Schul conducted two experiments, each designed to detect any difference in implicit learning between two groups of subjects. In one experiment, the implicit learning task was a simulation of a sugar factory. In the other experiment, the implicit learning task was a serial reaction time task involving reacting to the location of a disappearing and reappearing circle on a computer screen. The participants in each experiment were primed with a seemingly unrelated task: completing a word search puzzle. One group in each of the two experiments was given a word search puzzle that included motivational terms such as *excellence*, *aspiration*, and *win*. The second group in each experiment was given a word search puzzle with motivational neutral terms such as *carpet*, *hat*, and *topaz*. While the participants did not differ in their explicit motivation or explicit knowledge after completing the implicit learning task, there was a significant difference in performance between the two groups (Eitam, Hassin, & Schul, 2008, pp. 265–266). The word search puzzles were not directly related to the implicit learning tasks, but they had a measurable effect on learning. The implications for even the most seemingly insignificant aspects of the learning environment are profound.

Disequilibrium

The reader may recall a reference earlier in this paper to the fact that complex adaptive systems continually move between order and disorder, never settling in one state or the other. This very movement, or disequilibrium, engenders the flexibility necessary for the system's ongoing participation in the dance of co-creation. Gell-Mann considers the process of thinking a complex adaptive system. To view thinking in this way, to acknowledge the continual disequilibrium and its concurrent creative potential, is to invite questions about the place of such potential in formal learning environments.

A complex adaptive system does not exist in a state of total disorder; such a system is a chaotic one. Instead, there is always a certain degree of order present—some order, but not enough to lock the system into stasis. If the existing, dynamic order of thinking in an individual is an integral part of the context within which thinking takes place, then it stands to reason that the disequilibrium of each individual's thinking within each one's unique, dynamic learning landscape may be the most vital component to consider when designing formal learning environments. As we have seen previously, just before phase synchronization occurs in the brain, disequilibrium becomes pronounced. In the experiments we have discussed, there was a slowing of response time just before phase synchrony of the new skill took place. This might mean that a genuine change in the learning landscape of an individual may be preceded by some sort of confusion, awkwardness, or uncertainty. In learning a simple motor skill, this period is quite brief. Does this same process occur over a longer period for more complex tasks or skill acquisition? Do we allow for this in our classrooms? Is there time available for this kind of transition to take place?

Inquiry and the Search for Excellent Solutions

At this point, let us revisit a crucial feature of complex adaptive systems: the search for excellent solutions. The reader may recall that the theory maintains that complex adaptive systems engage in the search for excellent solutions to whatever problems are encountered. Without specifying what those problems might be, the implication is that they are co-transformations that require adjustment in order for the system to survive. These excellent solutions result in maximum fitness for the system. Maintaining maximum fitness allows the system to persist, and more than that, to thrive. How can a view of thinking as a complex adaptive system and the search for excellent solutions inform formal learning environments?

In complex adaptive systems, finding a single best solution is impractical, maybe even impossible, due to the constraints of time and the vastness (with respect to the searching agent) of the landscape within which the search takes place. As was previously mentioned, Holland and Kauffman have shown that, rather than search for a single best solution, the ability to adapt to an ever-transforming landscape requires finding one or more excellent solutions to the presenting problem. The assumption is that any number of excellent solutions may be discovered.

Contrary to this view of the possibility of many excellent solutions for a presenting problem, often formal learning environments are organized around the assumption that there are single best solutions to well-known problems, and that these best solutions, in most cases, have already been discovered. Building on this assumption, the role of the teacher is often seen as to provide students with this best solution information, referred to in this system as "knowledge." In turn, students are evaluated on their ability to demonstrate understanding of such knowledge in the form of "right" answers.

There are several significant consequences of this approach. One is that any answer that is not considered the right one, is considered wrong. This dichotomy contradicts what we know of the history of human thinking. Nowhere is this more evident than in the flow of scientific inquiry. If, for example, the theory of the earth as the center of the universe had been accepted as the single "right" one, then most of the ways we communicate about the cosmos via modern science would not have been developed. Piaget expressed this idea in a 1968 lecture on his theory of genetic epistemology.

> Scientific knowledge is in perpetual evolution; it finds itself changed from

> one day to the next. As a result, we cannot say that on the one hand there is the history of knowledge, and on the other its current state today, as if its current state were somehow definitive or even stable. The current state of knowledge is a moment in history, changing just as rapidly as the state of knowledge in the past has ever changed and, in many instances, more rapidly. Scientific thought, then, is not momentary; it is not a static instance; it is a process. More specifically, it is a process of continual construction and reorganisation.

Finding the single right answer spells the end of thinking. Since an important component (some might argue the most important component) of schooling is to engage students' thinking, it can be seen that the single right answer approach contradicts this aim. One might argue that the idea of the earth as the center of the universe was always wrong, but that people just didn't realize it until the real right answer—the earth as simply one of several planets that orbit the sun—was discovered. I would counter by saying that in itself is evidence enough for us to question the assumptions we believe to be true.

Dewey considered the problem of insisting that students get the right answer, as well. He wrote that it was "impossible … to exaggerate the hold that this attitude has upon teaching in the schools" (Dewey, Intelligence in the Modern World, 1939, p. 689). He said that one reason for the prevalence of the right answer approach was a misunderstanding of the alternatives, with many educators believing that without the resolution provided by such answers, students' minds would be left in confusion. In response to this attitude, Dewey commented, "The real alternative to settling questions is not mental confusion, but the development of a spirit of curiosity that will keep the student in an attitude of inquiry and of search for new light"(Dewey, Intelligence in the Modern World, 1939, p. 689).

Another drawback of the single best answer approach is that it defines the student's task as to find the answer rather than to think about the problem. The focus is shifted from the process to the goal. This subtle shift is critical in instilling a pattern of thinking I have often encountered in the secondary classroom. Since the goal is seen by students as to get the right answer rather than to think about a particular problem or situation, students tend to develop the skills they need in order to accomplish the goal. If the student has been able to figure out how the teacher thinks, getting the prescribed answer (in the prescribed way) may be easy. If not, and if that is the only way that is deemed acceptable, a student may rely on other skills to find the answer. These might involve copying the answer from the student who has figured it out, copying from the Internet, or stealing the answer key. The problem then expands from the original, seemingly simple question of right and wrong answers to the more complex question of ethically right and wrong actions. On several occasions I have been told in sincerity by students that these alternative methods of achieving the goal of the right answer were not wrong if one didn't get caught at them. Apparently to these students, since the only thing that really "counts" is the right answer and the final grade, the means of achieving it is of secondary importance.[1)]

So, what kind of approach in formal learning environments can support the search for excellent solutions? One possibility is that of guided inquiry. This is inquiry motivated by student-generated questions. The quality of questions generated by students varies widely, however, and it is one role of the teacher to guide students in formulating good questions. This is not to suggest that the teacher must have one right question in mind, which the students are required to guess. Rather, the teacher can encourage each student to evaluate his own questions until he can discern which of them are worth pursuing. There can be no right or wrong questions, only some that might lead to productive exploration and others that are unlikely to produce valuable experiences. There is an element of subjectivity involved, and the student's own intuition must be respected. By providing guidance within the context of the student's own interest and intuition, a teacher may encourage the confidence required to maintain rigorous inquiry.

What constitutes a good question is not, as one might suppose, the likelihood that pursuit of the answers will produce a correct result. On the contrary, a good question is one that stimulates productive inquiry regardless of the end result.

> "Good questions" are … good because they engage our minds in complex processes of analysis - uncovering unstated assumptions, and searching for evidence that will lead us to logical, reasonable conclusions. (Barell, 2003, p. 80)

Those reasonable conclusions may or may not produce a correct answer. The process of reasoning is what is most important. The purpose of formulating good questions, then, is to encourage thinking. Dewey points out that "the first stage of contact with any new material, at whatever age of maturity, must inevitably be of the trial and error sort" (Dewey, Democracy and Education, 1919). Of necessity, there is a certain amount of trial and error involved in thinking, particularly when a topic is first encountered. A recognition and accommodation of this trial and error phase of inquiry can aid in the search for excellent solutions.

Generating ideas and pursuing possible avenues of thought is time-consuming. The thinker makes false starts and wrong turns, encounters blind alleys, collapses in a heap, reconsiders, and starts again. It is all part of the search. This may seem to be a waste of time, particularly when the teacher or textbook is perfectly capable of providing a "right" answer without all the bother. However, there may be no quicker way to stymie student interest and motivation than to present material as if all the answers have already been found and the student's job is simply to memorize them. It is crucial to allow students to take the time they need to make their own discoveries. Providing the opportunity for students to discover answers for themselves also encourages them to develop invaluable thinking skills, which can make learning more interesting and effective.

Dewey, whose writing of 1916 seems almost to predict the current study of complex adaptive systems and Maturana and Varela's work in biology, advocates designing learning environments that encourage inquiry and exploration. This quote reminds one of Maturana and Varela's concept of structural coupling:

> A response is not just a re-action, a protest, as it were, against being disturbed; it is, as the word indicates, an answer. It meets the stimulus, and corresponds with it. There is an adaptation of the stimulus and response to each other. A light is the stimulus to the eye to see something, and the business of the eye is to see. If the eyes are open and there is light, seeing occurs; the stimulus is but a condition of the fulfillment of the proper function of the organ, not an outside interruption. To some extent, then, all direction or control is a guiding of activity to its own end; it is an assistance in doing fully what some organ is already tending to do. (Dewey, Democracy and Education, 1919)

The concept of structural coupling can inform the way teachers help guide thinkers in formal learning environments. With a view of thinking as a complex adaptive system within which curiosity, the potential for learning, is innate and learning itself proceeds continuously, the teacher can be seen as one who facilitates these processes rather than one who instigates them. Moreover, everyone involved in the formal learning environment can be seen as a co-creator in transforming individual learning landscapes.

Correct and True

Thinking about a problem is necessarily personal as it occurs in the unique personal contexts mentioned in previous sections. The thinker is engaged in a learning activity, discovering and making connections. Finding an answer, on the other hand, is seen as a process in which the individual learner has no voice. The answer has already been discovered, the single best solution has already been worked out by someone else, and the student's job is merely to memorize, reiterate, or duplicate it. This approach distances the student from the problem and lessens the possibility that the process of finding a solution will be incorporated into the student's conscious learning landscape, or that she will be able to find the prescribed solution at all. As Paley observed of her work with 3-year-olds, "Tempting as it may be to set the record straight [regarding whether or not a particular student's mother has a birthday, for example], I have discovered that I can't seem to teach the children that which they don't already know" (Duckworth, 1996, p. 158). What is true for a learner is that which has been incorporated into the learner's individual learning landscape. Thus, what is deemed correct may simply not be true in a particular learner's case.

Duckworth offers plenty of examples that illustrate this point. Her work, strongly grounded in that of Piaget, has led her to an approach to teaching that encourages students, no matter their ages, to become aware of their own ways of thinking and transforming conscious experience. This approach is student-centered and requires that the teacher stay attentive and actively engaged in the students' own reasoning processes. One important way the teacher stays engaged is by asking open-ended questions that offer opportunities for the students to examine and test their own ideas. Here Duckworth describes the process.

> Instead of explaining to the students, then, I ask them to explain what they think and why. I find the following results. First, in trying to make their thoughts clear for other people, students achieve greater clarity for themselves…. Second, the students themselves determine what it is they want to understand…. Third, people come to depend on themselves: They are the judges of what they know and believe. They know why they believe it, what questions they still have about it, their degree of uncertainty about it, what they want to know about it next, how it relates to what other people think. Any other "explanation" they encounter must establish its place within what they know. Fourth, students

> recognize the powerful experience of having their ideas taken seriously, rather than simply screened for correspondence to what the teacher wanted [sic]. Fifth, students learn an enormous amount from each other…. Finally, learners come to recognize knowledge as a human construction, since they have constructed their own knowledge and they know that they have. (1996, pp. 158–159)

The gifts of such an approach are apparent. Not only do Duckworth's students take an active role in their learning, driven by innate curiosity and guided by their own reasoning processes, but they also develop metacognitive skills. This metacognition can serve them in learning situations throughout their lives, as it is the key to learning how to learn.

Practice! Practice! Practice!

There is an old joke in the U.S. that goes like this:

> A tourist is walking down the street in New York and he stops someone to ask for directions. *"How do you get to Carnegie Hall?"* he asks. The respondent answers, *"Practice! Practice! Practice!"*

Carnegie Hall is a concert performance venue. For many artists, the chance to perform there represents the epitome of a career.

In addition the opportunity to explore for excellent solutions, the research suggests that learning at the conscious human level also requires time for practice and mastery. In Kelso's simple experiment with the cycling fingers, participants were not immediately able to perform the activity out of phase with the nearby basins of attraction. The change to the learning landscape required work and practice.

To many readers, this point may seem obvious. But the emphasis on testing and the requirements that more and more content be covered per term have resulted in less time for exploration and mastery in the typical classroom.

In addition to more time for practice, we need to provide a variety of options for practicing, including verbal, kinesthetic, and visual.

In Defense of Reinventing the Wheel

A common expression in English cautions one against "reinventing the wheel"—the implication being that rediscovering what has already been discovered by someone else is a waste of time. This may be one of the underlying beliefs of our current educational system. Seen from that perspective, the logic of encouraging students to achieve right answers makes sense. Such an approach theoretically avoids wasting time by giving students the knowledge of what has gone before. Presented in this way, knowledge is static, unchanging, correct.

However, if a human being is a complex adaptive system, and if learning is a dynamic of that system through which transformation occurs as a result of the experience of co-creating the world, then such an approach is, in fact, an utter waste of time. Seen from this point of view, the wheel must be invented again and again, by each one in his or her own way.

In this contradiction is the essence of a major struggle in educational practice. In an effort not to waste time and to demonstrate the "results" on which funding and public support depend, formal educational practice is designed to fill students' minds with data that can be measured and graded. This practice depersonalizes the educational experience, creates an environment in which students compete with one another for their places on the bell curve (Hartwell, 2001) and values getting "the right answer" over personal vision and the co-creation of meaning. Simultaneously, educators, parents and students themselves bemoan the lack of student engagement, low levels of critical thinking ability and high disillusionment with a system in which students are often seen as unable or unwilling to learn. We as a learning society can't have it both ways. We can choose either to set up flexible learning environments in which learners can take the time they need to create personal understanding or we can continue with the present system, thereby giving up the benefits of such an approach.

> Why is it, in spite of the fact that teaching by pouring in, learning by a passive absorption, are universally condemned, that they are still so entrenched in practice? That education is not an affair of "telling" and being told, but an active and constructive process, is a principle almost as generally violated in practice as conceded in theory. Is not this deplorable situation due to the fact that the doctrine is itself merely told? It is preached; it is lectured; it is written about. But its enactment into practice requires that the school environment be equipped with agencies for doing, with tools and physical materials, to an extent rarely attained. It requires that methods of instruction and administration be modified to allow and to secure direct and continuous occupations with things. Not that

> the use of language as an educational resource should lessen; but that its use should be more vital and fruitful by having its normal connection with shared activities. (Dewey, Democracy and Education, 1919)

Dewey's words ring as true today as they must have in 1916.

Another possibility is that everyone involved can actively engage in a search for excellent solutions to the dilemma of our present system. It seems likely that we are capable of generating many excellent solutions, and their efficacy in the changing learning landscape will surely change as well. Complex adaptive systems exist in an ever-changing state somewhere between order and chaos. They simply cannot exist in a rigidly ordered state, nor can they self-organize in a state of chaotic disorder. Maybe one secret of successful educational reform lies in the understanding and application of this idea. Instead of searching for the single best approach to education, our system might benefit from an acceptance, even a celebration of its transformational nature, that is, the necessity of its continual transformation and its ability to simultaneously transform its participants.

Summary and Questions

The study of complex adaptive systems suggests that beauty and organization may, under certain conditions, arise spontaneously as a result of the actions of many agents acting locally and without a specific leader. Such study generates an image of systems at many scales which are involved in continuous transformation, dynamic and vibrant. In such systems, the synergistic whole is, indeed, greater than the sum of its parts and inseparable from them. Viewed through a biological lens and brought into focus by the work of Maturana and Varela, this continuous transformation within and among nested and aggregate complex adaptive systems may be conceived of as the process of co-creating the world; each agent is a co-producer of a future fashioned out of myriad possibilities. In complex adaptive systems, flexibility is the key to success.

When these ideas are applied to thinking, many opportunities arise for reflection about how learning systems can be designed to best support human learning. The search for excellent solutions to the challenges of our current formal educational system might begin with questions as a point of departure. These might stimulate discussion, but might also encourage experimentation, which could generate more questions, and so on.

The point is not to find an answer, or even several answers. The underlying reality of complex adaptive systems is that they are always in a state of transformation. As such, successful solutions must themselves be flexible and subject to transformation. The challenge of such an adventure beckons those who dream of a world in which the joy of learning is the focus of formal learning environments—not entertainment, but the sweaty, difficult, exasperating, exhilarating process of bringing forth a world.

Here are some questions the reader might wish to consider. It is hoped the reader will have many more.

The Type 1 processes are unconscious, fast and efficient, capable of analyzing patterns too complex for the conscious mind to grasp, and continuously active. These processes are not available to the conscious mind, but they inform conscious learning. Is there a way to construct formal learning environments that support unconscious learning? Are there elements in our current designs that do so? If so, what kinds of unconscious learning is being supported? Is their effect positive?

What are the main purposes of formal education? What kinds of educational culture best support those aims?

Can the emerging understanding of complex adaptive systems and brain function productively inform formal educational design and practice? If so, how? If not, why not?

Note

1) See Brooks and Brooks, page 67.

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