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Complexity Theory 101 for Educators: A fictional account of a graduate seminar
Théorie de la complexité 101 pour éducateurs: compte rendu fictif d'un séminaire d'études supérieures

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Article abstract

The following fictional account of a seminar on complexity science and its relevance for education makes use of several real events. The first is an actual seminar that took place during the spring of 2005, in the Department of Secondary Education at the University of Alberta. The second is the collective creation of the Complexity and Education Online Glossary (McMurtry et al., 2004; see http://www.complexityandeducation.ualberta.ca). Furthermore, many of the ideas presented in this article are based on the definitions originally developed for that glossary.

COMPLEXITY THEORY 101 FOR EDUCATORS: A FICTIONAL ACCOUNT OF A GRADUATE SEMINAR

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ABSTRACT. The following fictional account of a seminar on complexity science and its relevance for education makes use of several real events. The first is an actual seminar that took place during the spring of 2005, in the Department of Secondary Education at the University of Alberta. The second is the collective creation of the Complexity and Education Online Glossary (McMurtry et al., 2004; see http://www.complexityandeducation.ualberta.ca). Furthermore, many of the ideas presented in this article are based on the definitions originally developed for that glossary.

THÉORIE DE LA COMPLEXITÉ 101 POUR ÉDUCATEURS: COMPTE RENDU FICTIF D'UN SÉMINAIRE D'ÉTUDES SUPÉRIEURES

RÉSUMÉ. Ce compte rendu fictif d'un séminaire sur la science de la complexité et sa pertinence en éducation se fonde sur plusieurs événements réels. Le premier est un séminaire qui a eu lieu au printemps 2005 dans le département d'enseignement secondaire de l'Université de l'Alberta. Le second est la création collective du Complexity and Education Online Glossary (McMurtry et coll., 2004; voir http://www.complexityandeducation.ualberta.ca). En outre, bon nombre des idées présentées dans cet article reposent sur les définitions élaborées à l'origine pour ce glossaire.

I am starting to feel a little nervous. I and two of my colleagues, Jillian and Jean-Michel, have volunteered to chair a lunch-hour seminar for our fellow graduate students in the Faculty of Education. The topic is complexity science and its relevance for educational research. Because we could not think of anything more original, we told the organizers to simply call it "Complexity Science 101 for Educators."

I hope the word "science" in the title does not put off those with a background in the humanities or social sciences. People in those areas are often surprised to hear that complexity science diverges radically from traditional, analytic scientific approaches and that it is quite compatible with critical and poststructuralist thought.

I see some familiar faces and some new ones. Samira, the president of the faculty's graduate student association, calls everyone to order and gives a succinct introduction: "Nice to see so many of you here today for this week's workshop. The topic is complexity science, something I myself know very little about. Angus, Jillian, and Jean-Michel have promised to give us a basic overview and do their best to answer any questions. Don't be shy. Remember, there's no such thing as a dumb question! So, without further ado, here they are."

Jillian, Jean-Michel, and I met a few days ago to discuss how to coordinate our roles in the seminar. We decided to each talk about an area of complexity and education with which we were most familiar, then answer questions and see what happened from there. I also got the job of giving a brief introduction.

Thanks for coming today and for your interest in the theoretical framework that Jillian, Jean-Michel, and I are using. Complexity science, which some people refer to as complex systems theory or dynamic systems theory, is a relatively new trans-disciplinary area of study. These days, it is pursued by researchers in everything from mathematics, physics, and biology, to the humanities, social sciences and philosophy. In education specifically, writers such as Doll (1993), Osberg (2005), and Davis and his collaborators (Davis & Sumara, 2006; Davis, 2004; Davis & Simmt, 2003; Davis, Sumara & Luce-Kapler, 2000) have sought to articulate and develop complexity-based ideas in the context of classroom education.

Jillian, Jean-Michel, and I have different backgrounds and different foci in our research, so we thought we would divide up the presentation accordingly. Jillian will start by describing some of complexity science's central concepts; I will discuss learning and knowledge from a complexity perspective, as well as complexity's application within human contexts; and finally, Jean-Michel will set out some of the practical ways in which complexivist insights can be brought to the classroom. Okay, Jillian, the floor is yours.

Jillian has a background in physics but joined the Education Faculty last year to study in the area of math and science education. "I thought I would start my explanation of complex systems and complexity science by saying what they are not," she begins. "That is, by comparing them to other types of systems and scientific methods..."

Most traditional Western science has been concerned with what we would classify as simple and complicated systems. A simple system behaves in a straightforward, mechanical, and linear manner, like the balls on a billiard table or an automobile engine. It has a limited number of variables or parts that interact in direct cause-effect relationships, such as the relationship between temperature and volume in a thermometer. If you understand the parts, therefore, you can predict and control the behaviour of the system as a whole. Simple systems are thus the "sum of their parts." The framework used to study them is classical Newtonian mechanics.

The principles and methods appropriate to the study of simple systems have often been used – or perhaps I should say misused – in the context of education, for instance, by *behaviourists who define learning as changes in behaviour directly caused by changes in the environment.*

Unlike simple systems, which only have a few variables or parts, complicated systems have a significant number of interacting variables or parts, which make precise prediction of those individual variables or parts very difficult. However, such systems are still the predictable sum of their parts; the problem is just one of accurate measurement. Statistical and probabilistic methods were therefore developed to understand their global, collective characteristics or behaviours. Phenomena generally thought to be complicated include magnetism, weather systems, and the movement of planets and stars.

Most educational research in the 20th Century has been framed by statistical approaches – for example, large-scale high stakes assessment, the normal curve, and intelligence testing. This has occurred despite the fact that many mathematicians and statisticians regard the application of statistical methods to human learning as inappropriate and misleading.

It is important to note that the probabilistic or statistical methods used to study complicated systems represent not so much a shift in thinking as an extension of the methods used to study simple systems. Unchanged is the fundamental assumption that phenomena are determinate and reducible to the sum of their parts.

Many phenomena, however, resist both simple and complicated methods of explanation. This third category of phenomena – complex systems – includes things like living cells, the human brain, languages, cities, and ecosystems. Traditional analytic methods of study are inappropriate for these systems because they are "more than the sum or their parts." As the philosopher Cilliers (1998) puts it,

> *A complex system is not constituted merely by the sum of its components, but also by the relationship between these components. In "cutting up" a system, the analytical method destroys what it seeks to understand. (p. 2)*

Complex systems thus embody possibilities exceeding the sum of their components, possibilities that emerge at the level of the system as a whole. One clear example of such emergence is the way a living human being has possibilities for action that go beyond the possibilities for action that a simple aggregation of his or her component atoms would have...

"Wait a second," says someone in the first row. It's Catherine, an experienced high school chemistry teacher doing her master's in science education. "Are you saying that analytic methods aren't any use when you are studying living things? What about modern medicine and biochemistry? They use pretty analytic techniques, and they seem to be doing quite well."

"Those disciplines are not really my area of expertise," Jillian admits. "But in any case, I don't think that people studying complexity are arguing that the analytic method is wrong; in fact, many of them come from a highly analytic academic background. They are just saying that it is not always very helpful when you are trying to understand some of the most interesting and important features of complex systems. For example, simply looking at individual neurons in the brain does not tell you that much about day-to-day human choices or consciousness. And looking at isolated persons does not take us very far in understanding pervasive social phenomena like economic inequalities.

"Anyway, before moving onto complexity's relevance to these types of human social issues – something that Angus and Jean-Michel have a little more experience with – I'd like to finish off by describing two of complex systems' most important characteristics, self-organization and adaptation...."

Complex systems are said to be self-organizing, because they emerge through the dynamic, non-linear interaction of their component parts. Since complex systems arise this way, rather than from the imposition of "top-down" instructions, their form of organization is often described as being decentralized, or "bottom up," in nature. Examples of this "bottom-up" form of organization include the way ants self-organize into anthills, birds into flocks, and humans into social and political collectives.

Although top-down processes can emerge within sufficiently complex systems, they always arise in and through the on-going, bottom-up activities of the system itself and never as a unidirectional, controlling cause (Juarrero, 1999). Examples of such "downward causation" include the way the conscious mind directs one's mental processes towards solving certain problems, or the way society constrains the actions of its members through laws.

A crucial consequence of complex systems' self-organization is that they cannot be reduced to, or understood in terms of, straightforward causal inputs and outputs. As Davis and Simmt (2003) write, they "change their own operations through operating" (p. 139) and thus resist direct, external control or accurate prediction – a quality that sets them apart from the mechanical systems studied by traditional analytic scientific methods. The philosopher and physicist, Capra (2002), offers a lucid illustration of this quality:

> *[W]hen you kick a stone, it will react to the kick according to a linear chain of cause and effect. Its behavior can be calculated by applying the basic laws of Newtonian mechanics. When you kick a dog, the situation is quite different. The dog will respond with structural changes according to its own nature and (nonlinear) pattern of organization. The resulting behavior is generally unpredictable. (p. 35)*

At the same time, complex systems are adaptive, because they change their own structure in response to internal or external pressures. A complex system's structure – that is, the dynamic relations among its component parts – adapts to, or couples with, its environment (though always in a way that is governed by its own self-organizing internal structure).

It is important to stress that complexivists do not hold the conventional assumption that the environment is something that is given or static, or that organisms and other complex systems can move towards some "optimum" fitness that perfectly matches *their environment. Instead, a complex system and its environment (which can be seen as a larger scale complex system) are involved in mutual and recurrent interactions that change them both. And many diverse adaptations may be viable in relation to a particular environment.*

Anyway – and this is my final point – an important consequence of adaptation is the importance of context and history. Complex systems are always open systems: They interact and co-adapt with their specific environments (Heylighen et al. 2007). To understand a complex system, then, one must take into account its particular history and context. For example, one cannot understand animal species without understanding the nature and history of the ecosystem within which they evolved; giraffes' extraordinarily long necks make little sense until one places them within the dynamic context of high trees and competition for scarce food sources. It is for this reason that complex systems are said to embody their history in their structure.

"These biological examples are all very interesting," says James, a friend of ours in social science education who is quite fluent in constructionist discourses. "But what do they have to do with people and the social and cultural systems that are most relevant to education?"

"Well, I wouldn't say that biology, at least human biology, is irrelevant to education," Jillian answers. "But your question is well-timed, because I think it's about time I handed things over to Angus, who will talk about complexity's relevance for learning, knowledge, and studying human social systems."

"Thank you, Jillian," I say, shaking off the last of the jitters that seem to accompany every public presentation. "Jillian talked about self-organization and adaptation in complex systems. These concepts fit almost perfectly with constructivist views of learning. As Piaget, Von Glassersfeld, and others have shown us, learners continually reorganize their ideas and expectations in order to adapt to their experiences and environment (Proulx, 2006). So complexity's focus is systems that *both* live *and* learn..."

While most of us would agree that this category of living, learning things includes many animals (including ourselves), complexivists assert that similar living and learning processes can be identified in a much wider range of phenomena – everything from microscopic organisms to social groups, economies, and ultimately the planetary biosphere.

As humans, we are deeply enmeshed in a large number of these systems. We ourselves learn, obviously, but so do our immune systems and the communities of practice in which we participate. Each of these different sorts of complex systems can be seen as a learner that emerges through the interactions of its component parts (which can themselves be seen as smaller scale complex, learning systems) and in relation to its environments (which can be seen as larger scale complex, learning systems). A company or academic discipline, for example, can be understood as a collective learner that emerges from the interactions of the people who compose it – and that is itself embedded in larger social organisms such as the education system or the economy.

Conditioned as most of us are by the dominant Western metaphor of knowledge as a kind of substance or representation and individual learners as knowledge containers, it can be difficult to conceive of learning in terms of relations and collectives. One illustration that I found helpful in changing my thinking is offered by Johnson (2001) in Emergence. *Drawing upon recent biological research, he describes how colonies or hives of social insects "learn" to avoid recurrent dangers and find long-term food sources, even though the individual members generally live very short lives and follow extremely rudimentary rules (such as simply following a certain kind of pheromone trail): "They think locally and act locally, but their collective action produces global behavior" (p. 74).*

A company that produces computers might be understood in a similar way. No one person understands all the physics, technology and communicative symbols that go into modern computers. And the personnel involved may change periodically. Yet their coordinated, collective action gives rise to something quite amazing. In a few minutes, Jean-Michel will talk about what it would mean to treat a class of students this way – that is, as a collective learner. For now, though, I'll stick to more general topics of learning and knowledge.

Knowledge, from a complexivist perspective, is embodied both in the dynamic relationships among a complex learner's component parts and in the dynamic relationships between that learner and its environment. In human contexts, for example, it is embodied both among an individual's neurons and in his or her collaborative relationships with others. Knowledge can also be seen in action terms; that is, a system's knowledge can be seen as its current repertoire of possible actions in relation to its environment. In fact, I am more comfortable talking about "knowing" than "knowledge," since it involves a living process rather than any kind of object or "fact" that can be considered apart from actual learners.

One radical consequence of this view of learning and knowledge – which I admit is not embraced by everyone in the complexity community – is that there is no such thing as "knowerless knowledge" waiting out there for someone to discover it. The complexivist writers that I am most familiar with – Fritjof Capra and Brent Davis, for example – take their cue on this issue from enactivist thinkers such as Maturana and Varela (1987). For enactivists, an organism's biological and experiential history is embodied in its dynamic structure (which sets the basis for its possible perceptions and actions at any given moment). As it recursively interacts with its environment (including other organisms) and adapts its structure in relation to it, the organism enacts its knowledge, or "world," in the sense that its particular structure implies or specifies that knowledge, or "world." We therefore do not so much perceive an objective, separate world as bring forth a world together through our co-existence.

"I am not sure I got all that," smiles Meiying, a PhD student with a background in literary analysis. "But it seems like complexity might have some things in common with postmodernist thought, especially with regard to the relational nature of knowledge. That surprises me, because I have always assumed complexity was just another 'scientific' discourse."

"You're right; I think there is a lot of overlap," I reply. "I'm certainly not an expert on postmodernism, but I do know that several complexivist writers, like Doll (1993) and Cilliers (1998), have explored these similarities pretty extensively. I guess one important difference concerns the role of biology and the more-than-human world. For complexivists, issues of knowledge, truth, and identity are not only a matter of human, intersubjective negotiation – they are also a function of the mutually affective relationships among all living systems. Even in the study of human learning, physical and biological factors are more than an inert backdrop; they have as important a role to play as culture. As the neuroscientist Donald (2001) writes, we are 'hybrid creatures,' our minds combining a biologically-based capacity for fuzzy, experiential analogizing with sharper, culturally-received symbolizing: 'We are hybrids, half analogizers, with direct experience of the world, and half symbolizers, embedded in a cultural web' (p. 157)."

"Still, I think that complexity and postmodernism have a lot more in common than people often think..."

One idea that I think complexity and postmodernism definitely share concerns the locality of discourses, that is, the conviction that knowledge can never be disentangled from particular locations, histories, contexts, and observers. As I described above, complexivists understand humans to be enmeshed in a large number of complex learning systems, from the cellular to the cultural and ecological. Each level, or learner, manifests emergent behaviours or possibilities that cannot be explained simply by looking at its component parts or environment.

Different explanatory discourses are therefore required for different levels and kinds of learners. For example, if an individual's sense-making activities are your focus, then you might make use of radical constructivism; but if you wish to study the relationships between people and the manner in which collective knowledge is generated, or silenced, then social constructionism may be more appropriate. Furthermore, no one discourse is necessarily more "basic" or "fundamental" than another. As Davis and Simmt (2003) write,

> *complex unities must be studied at the levels of their emergence... complexity science suggests that discourses concerned with different phenomena (such as radical or social constructivism – or neurology, ecology, or biological evolution) can be simultaneously incommensurate with one another and appropriate to their particular research foci. (p. 143)* [2]

Another question, this time from a first-year masters student I have not met before: "But aren't those two levels – the individual and the social – inextricably linked? How can you separate the two?

"You can't," I answer. "In complexity's worldview, at least as I understand it, nothing is ever really separate..."

In the case of individual-social relationships, for example, I think we could say that people are embedded or enfolded within social collectives, and that social collectives embody and unfold from those very persons and their interactions. Complexivists refer to such mutual connectedness as "nestednes."

Of course, similar insights about the dialectic relationship between individuals and social collectives can be found in discourses such as activity theory (Engström & Miettinen, 1999) and "communities of practice" (Lave and Wenger's 1991). Complexity, however, expands on these social constructivist discourses, arguing that both people and social collectives are enmeshed in a number of other larger and smaller scale biological, ecological, and cultural systems. Understanding a complex learner therefore always means attending not only to the level you are focused on, but also those above, below, and beside.

Recall, though, that complex systems are self-organizing and embody emergent possibilities that exceed the sum of their parts. This means that they have an integrity of their own that cannot be explained simply by looking at their component parts or the environment in which they are embedded. Indeed, it is precisely these characteristics that make a system a coherent unity, distinguishable from its environment and thus observable to others. A complex system is autonomous not in the sense that it is ever separate from its environment – because it is not – but rather in the sense that it governs its own behaviour and thus contrasts with its environment..

"Ahem," coughs James. "I'm waiting to hear how all these ideas 'play out' in actual human contexts. Can you give us some more concrete examples?"

"Jean-Michel is going to talk about how complexivist principles can be employed in the classroom. Before I turn things over to him, though, I'll talk a little about how ideas like self-organization and adaptation apply within the context of individual and social learning..."

As we heard, complex systems adapt in relation to their environments, but this adaptation never takes the form of direct, linear causation. That is because a complex system's behaviour is always as much a product of its own self-organizing, dynamic structure as it is of its environment. This characterization fits with the radical constructivist view of individual learning (Proulx, 2006). Experiences are not simply "taken in" by a learner; they are instead construed by that individual learner in light of his or her previous experiences.

Similar learning processes can be identified at the level of social collectives. My own research on professional groups like teachers, lawyers, and healthcare workers, for example, shows how they construe, in terms of their own collective knowledge and practices, influences from other professions and wider social processes, as well as how they resist attempts by governments and corporations to control their activities.

Canada's legal system, for example, can be seen as a self-organizing, adaptive learner. In terms of adaptation to specific historical contexts, Canada's common law has its roots in medieval Anglo-Saxon society. Its orientation towards individual property rights (especially land) and its tendency to measure all harms in monetary or exchange terms (for example, two silver coins are considered appropriate compensation for a severed left hand) seem to have begun at that time. Since then, the law has had to adapt to innumerable new dilemmas, including corporate law (which involved literally inventing a fictional legal "person" for financial and liability reasons) and, more recently, intellectual property, environmental harms, and biomedical issues such as cloning. The legal system has also been shaped by social conventions and government legislation that gives it near monopoly power to resolve all disputes. To a certain extent, it is embedded in the larger economic system and its disparities: Wealthy people and large corporations can "tip the scales" in their favour by hiring more and better lawyers than their less affluent opponents.

However, it is important to stress that such adaptation to contexts is not entirely determined by such external influences. As in all complex systems, self-organization has played a role as well. For example, the legal system will often resist external pressures to change, or assimilate new dilemmas within its existing framework (for example, the way non-material ideas like patents were analogically equated with physical property – thus "intellectual property"). And hard-fought cases can often help to bring significant change to the very social, economic, and political structures in which the legal system is embedded. For instance, recent judicial decisions have supported same-sex marriages in Canada, despite the reluctance of a large portion of the population.

Jaana, a visiting post-doc from Finland, catches my attention. "I have a comment about that last idea, the one about how a complex social collective's reaction to external forces is a function of its own self-organizing internal structure. That reminds me a lot of some Marxist thinkers I have studied. Cultural-historical activity theorists, for instance, claim that although external forces can influence or disturb social systems, the real driving force of transformations are the system's own internal contradictions."

"I hadn't thought of that," I say and pause for several seconds. "What you said reminds me of a course in Soviet philosophy I took many years ago. You're right; those two ideas probably do have a lot in common. We should write a paper on it!" I laugh. [3]

"Well, before we start writing anything," Jaana cautions, "I'd like to hear more about complexity's ethical stance. You mentioned some things earlier about how we are all connected and that we co-create a 'world' with other living systems. But I am still not sure what complexity says about out how we *should* act together."

"That's a tough question. And I think it would be fair to say that some complexivist researchers have not sufficiently thought out the ethical implications of their work. A number of thinkers, however, have started to articulate what a 'complexivist ethics' might look like...."

The philosopher Bai (2003) articulates several moral implications of complexity's ontology of relationality, nonlinearity, emergence, and interpenetration, including a participatory understanding of ethics:

> *We cannot avoid responsibility because we cannot avoid responding in some ways to each and every person and situation we encounter and thereby affecting the world in some ways. (p. 27)*

One of the enactivist thinkers I mentioned earlier, Varela (1999), wrote a short but excellent book called Ethical Know-How, *which explores what ethical responsibility might mean in a relational, emergent universe. Such know-how, he argues, is not based on adherence to abstract universal ethical rules; instead, it is enacted in our spontaneous everyday responses, as we negotiate embodied living in a complex and unpredictable world.*

Within the field of education specifically, Davis (2004, esp. chap. 14), suggests that the moral implications of complexivist ideas have found expression within ecological discourses that emphasize mindfulness and ethical action in relation to all living systems – including, but not limited to, humans. Karpiak (2000), writing in the context of adult learning and explicitly invoking complexity and related "new paradigm" sciences, writes about the importance of attunement, including "mindfulness and attentiveness to our interactions with others," "maintenance of cognitive flexibility," and "an attitude of curiosity and openness to new information or novel events" (p. 35).

Finally, Fenwick (2007) tackles "head on" complexity's silence on the topic of social responsibility, a concept central to her own field of adult and community education. After exploring some of the generative possibilities and dilemmas involved in bringing together these two strands of thought, she imagines what an educational vision of responsibility animated by complexity might look like. Making use of compatible concepts from Derrida (1990, 1995), Levinas(1981, 1985), and Deleuze & Guattari (1987), she suggests a number of alternative approaches to educational responsibility that build on complexivist ideas but at the same time incorporate considerations of power, positionality, language, and desire that are crucial in human systems.

> *These approaches include focusing on the immediate and imminent, opening to the possibility of connections, attuning to the other's call and responding to it, leaping into uncertainty by accepting the turmoil of sacrifice and secrets attending one's participation in response. (p. 109)*

In summary, I guess, I would say that complexity does have important ethical implications. But these implications are just starting to be explored and articulated. Since many of the most pressing problems of the 21st Century are concerned with complex connections – environmental, social, economic and so on – I suspect that these implications will continue to be explored. In any case, it's long past time for me to let

Jean-Michel to take over and tell us about complexity in the classroom. Sorry for taking up so much time, Jean-Michel.

Jean-Michel shrugs. "*De rien, mon ami*. That usually happens when you speak; I am used to it now," he jokes. "Complex views of education take their cue from the Latin word 'Educare,' which means to elicit, draw forth, bring about, or give rise to..."

This organic understanding of education involves both developing potentials and opening up novel possibilities for knowing and acting. As any experienced teacher will tell you, formal education involves not only explicit curricular goals, but also – perhaps more importantly – the unpredictable and exciting interactions, ideas and relationships that emerge among students and teachers. Education also affects – and is affected by – the wider social, cultural, and ecological systems in which schools are embedded.

As Angus mentioned, complexivists see learning and knowledge as emerging in a simultaneous and intertwining manner at multiple levels, not only at the level of the individual. In fact, for teachers, who often have 30 or more students in a class, the level of the classroom collective is arguably the most important cognitive level to focus on. Seeing the classroom collective as a complex learner in its own right may at first seem odd, but think about how often we as teachers all talk about classes having a "personality." We might say that "that class behaves badly," for example, even though we get along with all the students individually.

The question for educators thus becomes, how to ensure the conditions necessary for emergence of both individual and – especially – collective learning and knowledge...

"Wait a second," says Deepak, a second year PhD student with whom I share many classes. "I thought that, given time, people pretty much automatically coalesce into social collectives, like what you said earlier about ants self-organizing into anthills, and birds into flocks."

"That's true," Jean-Michel answers. "Given sufficient time, social collectives of one sort or another usually do take form. The problem is that in classrooms this social dynamic only rarely emerges around the subject matter; too often it centres on matters of discipline or students' preoccupation with the social project of 'fitting in.' I guess I should amend what I just said. What you are trying to foster as an educator is not just any type of collective learning; you are hoping that it will emerge around a particular subject matter, whether that be mathematics, history, or literature..."

In any case, several prominent educational authors have brought forward ideas about what a complexivist curriculum might look like. Common to all of them is a rejection of traditional, rationalist notions of curriculum that emphasize linearity, control, learner passivity, and knowledge. If you see learners as dynamic, self-organizing, and adaptive – as complexivist educators do – such traditional notions become not only unrealistic but actually stifling.

A complex notion of curriculum aims to nurture these dynamic learning processes, setting boundaries that prompt learners to engage with subject matter – without attempting to predict or control learning. Instead of trying to move students in a linear way from a predefined point A to a predefined point B, as rationalist curricula would have us do, a complexivist curriculum is about expanding the space of the possible, at both the individual and collective levels.

Doll (1993), for instance, has proposed a new approach to curriculum based on the "four Rs" of Richness, Recursion, Relations, and Rigour. However, the authors I am most familiar with, and the ones that most directly address the issue of collective learning and knowing, are Davis and his collaborators (Davis & Sumara, 2006; Davis, 2004; Davis & Simmt, 2003; Davis, Sumara & Luce-Kapler, 2000). In Davis and Simmt (2003), for example, a number of conditions are proposed for the emergence of collective learning – conditions that are especially important in classroom contexts: internal diversity, internal redundancy, decentralized control, enabling constraints, and neighbouring interactions.

The first condition, internal diversity, *is the source of a system's intelligence and creativity. It refers to the variety of backgrounds, interests, knowledge, abilities, and personalities within a typical classroom, as well as respectfully allowing them to contribute to the richness of lessons. The second…*

"Wait a minute," James speaks up. "You guys are doing it again. You're talking too abstractly. Could you give us practical examples for these conditions, so that we can relate them to our actual lives in education?"

"Yes, I suppose that would be more helpful," Jean-Michel admits. After a few moments of reflection, he says, "Angus, Jillian, remember our graduate class last term, the one where we worked together to design and write definitions for the interactive Glossary for the Complexity and Education website. I think that it would offer a good example of collective learning. What do you think?"

Jillian and I look at each other and nod. "Sure," she says. "It certainly shows the first condition of internal diversity, since we all brought our own background and knowledge to the glossary project. I came with a pretty good grasp of complexity's basic ideas and relation to other scientific discourses. You brought your knowledge and experience of classrooms and constructivist theories of learning. Angus used his general knowledge of complexity and background as a writer and editor to make all the definitions we wrote more accessible and consistent with one another. And of course all the other students contributed in their own way too."

"*Oui, exactement*!" Jean-Michel affirms. "I guess you covered that condition pretty well, so I'll move onto the next one…"

The second condition, internal redundancy, *is the complement to diversity. It is concerned with similarities in culture, language, history, and experiences – that is, the* *common ground that enables a class room collective to interact and maintain its coherence, even though individual members of the class may change. In our class, for example, redundancy took many forms – not only our language and culture, but also our shared experiences as a class, our common interest in the subject matter of complexity and education, and our group goal of creating a glossary. There was also sufficient overlap in our knowledge of the subject; if one person was absent, others could step in...*

"Just a second," says Meiying. "This idea of common ground, or redundancy, reminds me a little of what Foucault called 'common knowledge': powerful belief systems that define what is 'true' or 'false' and 'normal' or 'deviant' – and at the same time exclude other ways of being. How can you be sure that what emerges in the classroom doesn't reinforce powerful interests and silence other voices?"

"I suppose that is a danger we must always be aware of as educators," Jean-Michel answers. "Perhaps one advantage of these conditions is that they prompt us to consciously consider issues like diversity, commonality, and control (as you will see, that relates to the next condition)." He pauses for a second and then adds, "At the same time, I am not sure that we can ever do without *some* form of common ground in the classroom. As Giroux argues, we as educators need to *both* affirm diversity *and* find ways to articulate shared goals and values (Stevens, 2002). I personally would like to see someone examine more deeply the relationship between complexity and theories of power. I suspect there may be some productive tensions. For instance, Foucault's view of power as a dynamic, contestable relation – rather than a thing – fits well with complexity's relational epistemology. As does his focus on both individual and social bodies (O'Farrell, 2007). "*En tout cas... excusez moi.* In any case, let us turn to the third condition: decentralized control..."

Decentralized control *means changing the classroom dynamic from one in which the teacher manages information and students in a "top-down" manner, to one in which the teacher and students participate together (albeit in somewhat different roles) in the emergence of powerful, collective learning experiences that cannot be precisely controlled or predicted. For instance, in our class, the key terms we sought to define in the glossary were identified collectively. People worked individually or in pairs to come up with definitions, and each definition was critiqued and edited by others in the group. The overall visual design of the glossary – a "tree" with "clickable" terms for branches – emerged part way through the project, during a class discussion. The glossary was thus created in a decentralized, "bottom up" manner, and the shape it ultimately took could not have been predicted at the start.*

The fourth condition has to do with setting appropriate boundaries. Complexity does not advocate "anything goes" in the classroom; rather, the aim is to establish enabling constraints – that is, structures or boundaries that allow rich learning possibilities to emerge. The approach is similar to that of a soccer or basketball game where the rules, although constraining, enable the emergence of dynamism, creativity, and diversity. In *our class, the professor offered us the opportunity to create an online glossary. Constraints included the requirement that our work be relevant to complexity theory and education, that we show each other the proper respect, and that we finish our work within a certain timeframe. However, these constraints also left us a great deal of freedom to express ourselves. In one sense these constraints were limiting, but in another they were actually liberating, since they provided a framework through which we could all express and coordinate our differing views. That's the paradox of enabling constraints.*

The final condition is neighbouring interactions. *This does not simply mean that students should work together physically in groups. Instead, it means that individual ideas and interpretations be allowed to interact, or "bump up," against one another, creating the potential for novel, innovative, and insightful knowledge to emerge. Students' diverse interpretations thus become important "building blocks" in lessons. Obviously, this was the case in our glossary project. Even though most of the definitions were originally written by individuals, we all critiqued and edited them. There was lots of intellectual interaction and "bumping up" of ideas...*

"That sounds like a great class," says Catherine. "And I am sure you each learned a lot. But still I don't see how you can say that 'collective knowledge' emerged that was 'more than the sum or its parts.'"

"I'll try to answer that one," I say. "The glossary itself was an expression of the collective knowledge that emerged in that class. And this knowledge was not something that could have been predicted simply by looking each person's original individual knowledge..."

In the first place, our individual ideas changed through our interaction; each of us adapted his or her thinking after hearing what the other people had to say. We also built on each other's ideas, making links that none of us had made before and opening up new intellectual possibilities. As a class, then, we had a wider range of possibilities for acting than we could have had as a mere collection of isolated individuals.

Even if you looked at our individual knowledge after completing the glossary project, I think it would fall short of the collective knowledge produced. I personally had final responsibility for compiling, proof-reading, editing, and ensuring consistency within the glossary. Although I learned a great deal from the experience, the knowledge enacted in the glossary greatly exceeded my own knowledge. It was not as if each definition "went into my head" and then found its way onto the final document. Rather, I had the impression that I was nurturing and trimming a plant that had a life of its own. Indeed, I regularly return to the glossary to learn new things.

To put it another way, the collective knowledge enacted through the glossary seemed to exceed the knowledge of all the individual people who contributed to it. Each definition had been read and critiqued over time by multiple people and had gradually taken shape in relation to the other terms and the organization of the glossary "tree" as a whole. I have no doubt that the glossary "knew" things that none of the individuals involved did...

"Now that I think of it," Jean-Michel interjects, "this seminar could be seen as a case of collective emergence too. After all, Jillian and Angus and I coordinated our presentations and built on each other's ideas. Jaana and Angus made a new and unexpected link between complexity's idea of self-organization and activity theory's concept of internal contradictions. As a group we haven't been together long, but it still seems as though we have opened up some new possibilities for thinking and acting.

"Congratulations, you emergent learning collective!" Jean-Michel declares with a smile. With that, the other graduate students laugh and begin to leave. There are papers to write, marking to be done, and classes to attend and teach. Jillian, Jean-Michel, and I watch as our seminar group breaks up. I look at their faces and wonder if they too feel a tinge of regret, as though something has come into being and then faded away, never to be repeated in exactly the same way again.

NOTES

1. Although the terminology differs slightly, this classification is based on one originally identified by the influential physicist Warren Weaver in his 1948 article entitled "Science and Complexity."
2. A similar view regarding the irreducibility of discourses concerned with different phenomena has been expressed by Nobel laureate Phillip Anderson. In his classic 1972 paper, "More is Different: Broken Symmetry and the Nature of the Hierarchical Structure of Science," he writes that no field of science is necessarily more fundamental than another. Disciplines concerned with larger scale phenomena, such as chemistry, molecular biology and medical sciences, have unique "complications" and new types of behaviour that cannot be entirely reduced to particle physics or other rules originating at a more "fundamental" level (p. 396). A comparable point could be made about the social sciences and how they cannot be dismissed as merely vague extrapolations of the "hard" sciences.
3. See McMurtry (2006) for a paper on this topic.

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