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Complexity as a theory of education

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Educational research, as a domain of academic inquiry, is a relatively young field. Most of its major journals have been established since the 1960s, and only a few of them were in place a century ago. University-based colleges and faculties of education are similarly recent. Very few have been around for more than a half-century.

For the most part, when they were first established, colleges and faculties of education drew their personnel from specialists in psychology, sociology, history, philosophy, management, and the subject matter areas. And even though the situation has changed so that a huge majority of current faculty members have been credentialed by schools of education, the derivative nature of the field continues to be manifest in the names of its subfields and departments: *educational* psychology, *educational* philosophy, *educational* history, mathematics *education*, and so on. Few branches, with the obvious exception of curriculum studies, can justly be seen as proper to education.

Given this background, it is not surprising that educationists have a longstanding habit of importing theoretical frames and methodological approaches from other domains and disciplines. In this article, we examine some of the issues around this tendency, arguing that there are emergent qualities to educational research and curriculum studies that have not (and cannot) be represented in any of the fields from which they have drawn. In particular, we look toward the transdisciplinary and participatory domain of complexity theory as a means to make sense of the emergent character of educational research—ultimately arguing that complexity theory might be construed as a properly educational theory. We do not regard it as a frame that can be simply adopted, but an emergent conversation that compels participation (see Stewart & Cohen, 1997). In the process, we offer a series of critiques of the established practice of carving educational inquiry into subdisciplines that map tidily onto the grander academic world.

Transphenomenal—the nature of educational forms

Not unlike educational research, complexity thinking is young and evolving—and as we develop, it refuses tidy descriptions and unambiguous definitions. It has captured the attentions of many researchers whose studies reach across traditional disciplinary boundaries. For example, the following phenomena are currently under investigation by researchers who align themselves with this emergent school of thought:

- How does the brain work? Now that researchers are able to watch brain activity in real time, it has become clear that many long-held beliefs about its structure and dynamics—that is, assumptions about what thought and memory are, how learning happens, and so on—are misinformed if not completely mistaken (cf. Zull, 2002).
- What is consciousness? Over the past century, many neurologists, psychologists, and sociologists have attempted to present definitions and discipline-specific explanations of self-awareness, but it has become increasingly clear that none of these contributions

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is up to the task of making sense of human consciousness of self and other-than-self (cf. Donald, 2002).

- What is intelligence? IQ scores have been climbing steadily for the past century, at a pace that cannot be explained in terms of biological adaptation, improved nutrition, or educational intervention. It appears that the sort of spatio-logical abilities that are measured by IQ tests must be readily influenced and enabled by experience and context (cf. Johnson, 2005). What are the conditions that contribute to increases in IQ? Can they be manipulated? How is IQ related to or reflective of a broader, more encompassing conception of intelligence?
- What is the role of emergent technologies in shaping personalities and possibilities? The most creatively adaptive humans—that is, young children (Deacon, 1997; Gopnik, Meltzoff, & Kuhl, 2000)—are able to integrate the latest technologies into their existences in ways that older, less plastic adults can only envy. What might this mean for formal education, both in terms of pragmatic activity and with regard to common understandings of the purposes of schooling?
- How do social collectives work? Popular assumption has it that the actions and potentialities of social groupings are sums of individual capacities. Yet it is becoming more and more evident that, on occasion, collectives can vastly exceed the summed capacities of their members (cf. Bloom, 2001). How does this happen? Can these situations be orchestrated? What might this mean for classrooms, school boards, communities, and so on?
- What is knowledge? Even the most static of domains—including formal mathematics, the hard sciences, and fundamentalist religions—can be readily shown to be adapting to the shifting interests and obsessions of societies, being led as much as they lead (cf. Plotkin, 1994).
- What is education for? If one seriously considers the range of theories and philosophies invoked in current discussions of education, it is obvious that there is little agreement on what formal education is doing, much less on what it is intended to do.

On first blush, it might appear that the only common theme across such questions is that their answers are anything but self-evident. However, a closer look reveals some deep similarities among the phenomena addressed.

For example, it might be argued that each of these phenomena is pointing toward some sort of system that *learns*. Brains, social collectives, bodies of knowledge, and so on can all become broader, more nuanced, capable of more diverse possibilities. Further, each of these phenomena is *emergent*—that is, each arises in the interactions of many sub-components or agents, whose actions are in turn enabled and constrained by similarly dynamic contexts. In very different terms, it is not always clear where one should focus one's attentions in order to understand these sorts of phenomena. For instance, to research consciousness or intelligence or knowledge, does it make sense to focus on the level of neurological events? Or personal activity? Or social context? Or physical setting?

The emergent realm of complexity thinking answers that, to make sense of the sorts of *transphenomena* mentioned above, one must "level-jump"—that is, simultaneously examine the phenomenon in its own right (for its particular coherence and its specific rules of behavior) and pay attention to the conditions of its emergence (e.g., the agents that come together, the contexts of their co-activity, etc.). This strategy is one of several that have been developed within complexity research, and it stands in stark contrast to, for example, the individual-focused emphases of imported frames anchored in behaviorist psychology or

constructivist epistemology. As the argument goes, such emphases might make sense in the context of a laboratory or a one-on-one engagement, but they are simply inadequate for the multi-layered, intertwining happenings of a real-time classroom.

Transdisciplinarity—the nature of educational practice

As a coherent realm of discussion, complexity thinking has only come together over the past 30 years or so. Through much of this period, complexity has frequently been hailed as a "new science." Although originating in physics, chemistry, cybernetics, information science, and systems theory (among other domains), its interpretations and insights have increasingly been brought to bear in a broad range of social areas, including studies of family research, health, psychology, economics, business management, and politics. To a lesser, but accelerating extent, complexity has been embraced by educationists whose interests extend across such levels of activity as neurological processes, subjective understanding, interpersonal dynamics, cultural evolution, and the unfolding of the more-than-human world (e.g., Doll, 1993; Mason, 2008; for a review see Davis & Sumara, 2006).

This sort of diversity has prompted the use of the adjective *transdisciplinary* rather than the more conventional words *interdisciplinary* or *multidisciplinary* to describe complexity studies. Just as *transphenomenality* entails a sort of level-jumping, *transdisciplinarity* compels a sort of border-crossing—a need to step outside the limiting frames and methods of phenomenon-specific disciplines. Transdisciplinarity is a term that is intended to flag a research attitude in which it is understood that the members of a research team arrive with different disciplinary backgrounds and often-different research agendas, yet are sufficiently informed about one another's perspectives and motivations to be able to work together as a collective.

The history of the word *transdisciplinary* is useful to understanding the way that education, as a domain of inquiry, is positioned as more a participant-in-the-production-of-ideas than an importer-of-ideas within a complexity frame. Although there is some debate as to who coined the term and when it was first used, there is general agreement that educational issues figured prominently from the beginning. By some accounts, Jean Piaget was the first to propose the notion in the early 1970s in reference to problems that transcend the boundaries of conventional academic disciplines. Others attribute it to Basarab Nicolescu who, while principally concerned with questions in physics, related the term to the educational problematic. Whatever the case, not only has education been part of the conversation, the domain has been characterized as among the most complex of human projects.

The transdisciplinary character of complexity thinking makes it difficult to provide any sort of hard-and-fast definition of the complexity movement. Indeed, many complexivists have argued that a definition is impossible. Complexity thinking might be positioned somewhere between a belief in a fixed and fully knowable universe and a fear that meaning and reality are so dynamic that attempts to explicate are little more than self-delusions. In fact, complexity thinking commits to neither of these extremes, but listens to both. Complexity thinking recognizes that many phenomena are inherently stable, but also acknowledges that such stability is in some ways illusory, arising in the differences of evolutionary pace between human thought and the subjects/objects of human thought.

The fact that complexity thinking pays attention to diverse sensibilities should not be taken to mean that the movement represents some sort of effort to embrace the "best" elements from, for example, classical science or recent postmodern critiques of scientism. Nor is it the case that complexity looks for a common ground among belief systems. Complexity thinking is not a hybrid. It is a new attitude toward studying particular sorts of phenomena

that is able to acknowledge the insights of other traditions without trapping itself in absolutes or universals. Further to this point, although it is tempting to describe complexity thinking as a unified realm of inquiry or approach to research, this sort of characterization is not entirely correct. In contrast to the analytic science of the Enlightenment, complexity thinking is not actually defined in terms of its modes of inquiry.

It is this point that most commonly arises in popularized accounts of complexity research: The domain is more appropriately characterized in terms of its objects of study than anything else. In an early narrative of the emergence of the field, Waldrop (1991) introduces the diverse interests and the diffuse origins of complexity research through a list that includes such disparate events as the collapse of the Soviet Union, trends in a stock market, the rise of life on Earth, the evolution of the eye, and the emergence of mind. Other writers (e.g., Prigogine, 1997; Stewart & Cohen, 1997) have argued that the umbrella of complexity reaches over any phenomenon that might be described in terms of a living system—including, and of immediate relevance to this discussion of educational research, bodily subsystems (such as the brain or the immune system), consciousness, personal understanding, social institutions, subcultures, cultures, and species. In a similar vein, in our own work we have argued that, for educationists, complexity research might be productively understood as the study of learning and learning systems—a notion that encompasses individuals, social groupings, bodies of knowledge, cultures, and species as well as the contexts that are implied when such "agents" are specified (Davis, Sumara, & Luce-Kapler, 2008).

Of course, the strategy of list-making is inherently problematic, as it does not enable discernments between *complex* and *not-complex*. To that end, researchers have identified several necessary qualities that must be manifest for a phenomenon to be classed as complex. For example, complex phenomena are self-organizing, self-maintaining, and tend to be nested within (arising from and giving rise to) other systems. These qualities might be applied to a range of phenomena of interest to educationists, including individual sense-making, teacher–learner relationships, classroom dynamics, school organizations, community involvement in education, bodies of knowledge, and culture.

Clearly, such a sweep may seem so broad as to be almost useless. However, the purpose of naming such a range of phenomena is *not* to collapse the diversity into variations on a theme or to subject disparate phenomena to a standardized method of study. Exactly the contrary, the intention is to embrace the inherent complexities of diverse forms in an acknowledgment that they cannot be reduced to one another. In other words, these sorts of phenomena demand modes of inquiry that are specific to them.

Interdiscursivity—the nature of educational discussions

One of the major issues with the notion of *transdisciplinarity* is that the discourses that support and are supported by various disciplines are commonly seen as incompatible, if not flatly contradictory. This particular issue is manifest in contemporary 'paradigm wars' in which, for example, modernist sensibilities are pitted against postmodernist, and analytic orientations are often contrasted with ecological. Complexity thinking provides a means around these apparent impasses: it does so by emphasizing the need to study phenomena at the levels of their emergence, oriented by the realizations that new stable patterns of activity arise that are specific to the emergent system.

This piece of advice requires that researchers pay particular attention to the paces of evolution for the phenomena at hand. For example, the biology of a species transforms over millennia and eons, and is thus sufficiently stable to lend itself to the assumptions and methods of analytic science. By contrast, other phenomena, such as a culture's symbolic

tools, not only evolve more quickly, but are subject to very different sets of influences. Analytic methods are simply inappropriate for making sense of such disperse, rapidly changing, intricately entangled sets of phenomena.

It is thus that we would describe complexity thinking as a sort of *interdiscourse*. A *discourse* is a structurally coherent domain of language use—along with the activities associated with the use of that language—that organizes and constrains what can be said, done, and thought. Every discourse has its own distinctive set of rules, usually operating implicitly, that govern the production of what is to count as meaningful and/or true. Discourses always function in relation to or in opposition to other discourses. No discourse stands alone, although some (such as fundamentalist religion, scientism, or modernism) lay claim to a certain totalized and exclusive understanding of the universe. By attending to evolutionary pace, complexity thinking enables and compels a simultaneous appreciation of the insights of such disparate discourses as post-structuralism and analytic science. Notably, as a collective, educational researchers have acknowledged this point. Discourses as diverse as analytic science and post-structuralism are prominently represented in the current research literature. What is not so well represented, within single publications, at least, is the necessity of interdiscursivity. Indeed, most often in the contemporary literature, discourses are presented as oppositional rather than complementary. This sort of conclusion is inevitable if the transphenomenal nature of educational "objects" is not taken into consideration. This argument may be even more germane to curriculum studies, given the inherently transphenomenal, transdisciplinary, and interdiscursive character of the domain. To that end, we move now to a discussion of the emerging pragmatics associated with a complexivist mindset.

Pragmatics—moving beyond description

The transphenomenal interests, transdisciplinary emphases, and interdiscursive nature of complexity thinking are, we have argued, well fitted to the nested, evolving, and intertwining phenomena that are of concern to educational researchers. It is another matter, however, that renders complexity especially well suited to the realm of formal education.

Another of the problems with the importation of theoretical frames from psychology, sociology, and other tributary domains is that the borrowed theories tend to be concerned mainly with *description*. That is, they are not oriented by the principal and *pragmatic* project of educators of prompting learners toward particular, prespecified sets of competencies. Descriptions of complex phenomena and processes are clearly useful, but insufficient within a domain construed in terms of effecting change—which, although a matter of frequent debate, is how formal education tends to be popularly understood.

On this point, we do not mean to suggest that complexity thinking is the *only* pragmatically oriented frame. Others that have been taken up by educational researchers in recent decades include psychoanalysis and, to a much lesser extent, Eastern mindfulness traditions. Complexity thinking shares with these frames the conviction that transformations of learning systems cannot be understood in linear or mechanical terms and that any attempt at such transformations is necessarily a deeply ethical matter than must be undertaken with caution, humility, and care (Stewart & Cohen, 1997).

Of course, as has been foregrounded by critical theorists over the past several decades, the project of effecting change is neither innocent nor benign. Questions that must be addressed include, "Whose conception of change?", "Where does the authority rest?", and "Who benefits?" (We could go on.) Educational research that has been oriented by subject-centered constructivist theories, for example, tends to be aimed toward "doing things

better"—ensuring better comprehension of topics, developing more effective assessment strategies, and so on—thereby side-stepping questions of the social impact or the cultural relevance of the topics to be taught and evaluated. In prompting attentions to the nested and co-implicated aspects of the educational project, questions of *how* to teach are often considered independently of questions of *why*, *who*, *where*, and *what*.

The point? For a teaching species in a complex and ever-evolving world, it is troublesome to conceive of education strictly in terms of top-down, ends-driven structures. This is not to say that formal education can do without formal organizations or explicit curricula. The point is, rather, that education is better understood as being oriented toward the as-yet unimagined—indeed, the currently unimaginable. Such a "goal" can only be understood in terms of exploration of the current spaces of possibility. Education and educational research conceived in terms of expanding the space of the possible rather than perpetuating entrenched habits of interpretation, then, must be principally concerned with ensuring the conditions for the emergence of the as-yet unimagined. We would align these suggestions with Pinar and Grumet's (1976) development of the notion of verb *currere*, root of *curriculum* (along with a host of other common terms in education, including *course*, *current*, and *recursive*), through which they refocused attentions away from the impersonal goals of mandated curriculum documents and onto the emergent and collective processes of moving though the melée of present events.

In recent years, there has actually been a rapid growth in understandings of the sorts of conditions that must be in place to allow the emergence of such expansive possibilities (Johnson, 2001). Knowledge of these conditions has been applied, for example, in efforts to re-establish devastated ecologies and, as already mentioned, within the corporate sector to improve the viability and productivity of various industries. This knowledge has also been adapted and elaborated by a handful of educational researchers to structure classroom and research collectives (see Davis & Sumara, 2006, for an elaborated discussion). In particular, we have investigated educational import of the following conditions:

- internal diversity,
- internal redundancy,
- neighbor interactions, and
- decentralized control.

Space prohibits us from offering an in-depth discussion of these conditions, and so we offer only brief descriptions of these conditions and their possible relevancies. To render the discussion manageable, we have elected to focus on one particular level of complex activity: the transformation of a group of affiliated but independently acting agents into a unity in which personal aspirations contribute to grander collective possibilities. The discussion is oriented by the assumption that a successful collective is not just more intelligent than the smartest of its members, but that it presents occasions for all participants to be smarter—that is, to be capable of actions, interpretations, and conclusions that none would achieve on their own. In other words, each of the interdependent conditions discussed below is simultaneously a reference to global properties of a system and to the local activities of the agents.

The condition of *internal diversity* has been used to discuss the importance of, for example, the tremendous amount of unexpressed "junk" DNA in the human genome, the range of vocational competencies in any large city, the biodiversity of the planet, and the specialized functions of different brain regions. In each case, the diversity represented among units/parts/agents is seen as a source of possible responses to emergent circumstances. For instance, if a pandemic were to strike humanity, currently unexpressed DNA sequences might

bestow immunity upon a few people, and hence ensure the survival of the species—an intelligent response to unforeseeable circumstances. A differently intelligent response to the same circumstances (and a 'more' intelligent response, from the perspective of most members of the species) might arise among the interactions of a network of researchers with expertise in such diverse domains as virology, immunology, sociology, entomology, and meteorology. A critical point here is that one cannot specify in advance what sorts of variation will be necessary for appropriately intelligent action, hence the need to ensure and maintain diversity in the current system.

Our linking of systemic intelligence with internal diversity in the preceding paragraph is deliberate. Internal diversity defines the range and contours of possible responses. On the level of collective human action, there are important and usually broad diversities in any social grouping, no matter how homogeneously conceived. However, as demonstrated by certain religious groups, classrooms, and other structures that are in one way or another rigidly governed and/or insulated from grander systems, the possibility for expression of relevant diversities can be readily suppressed, thereby minimizing the opportunities for innovative collective action.

With specific regard to classroom settings, we are prompted here to offer a critique of those "cooperative learning" and collaborate group-based strategies that are organized around formal roles and instrumental, close-ended tasks. One cannot impose diversity from the top down by naming one person a facilitator, another a recorder, and so on. Diversity cannot be assigned or legislated; it must be assumed to be present. Similarly, it is unlikely that diversity, even if expressed, will be recognized and valued if the task set for a collective is trivial.

The complement of internal diversity of a system is *internal redundancy*, a term that is used to refer to duplications and excesses of those aspects that are necessary for complex co-activity. For example, in order for a group of historians to reconstruct some portion of Egypt's past, it is not necessary that everyone be able to interpret hieroglyphics. However, this sort of redundancy would likely be highly useful. In a social grouping, redundancies typically include common language, similar social status of members, shared responsibilities, constancy of setting, and so on. Such redundancies tend to fade into the backdrop of social action and are only pulled into focus when there is some sort of rupture in one or more of them. In fact, at least among humans, there is vastly more redundancy than diversity. This sort of deep sameness is vital. A complex system's capacity to maintain coherence is tied to the deep commonalities of its agents. As demonstrated by the ways that some people's brains recover from strokes, some companies cope with employee disloyalty, and some ecosystems adapt to the loss or introduction of new species, redundancy among agents is what enables a system to cope with stress, sudden injury, and other impairments.

Redundancy thus plays two key roles. First it enables interactions among agents. Second, when necessary, it makes it possible for agents to compensate for others' failings. It is in these senses that redundancy is the complement of diversity. Whereas internal diversity is outward-oriented, in that it enables novel actions and possibilities in response to contextual dynamics, internal redundancy is more inward-oriented, enabling the habituated, moment-to-moment interactivity of the agents that constitute a system.

An upshot, perhaps obvious, is that educators and educational researchers who are interested in interactivity in a complex collective must attend to the common ground of participants. Again, much of the necessary redundancy can usually be assumed to be present. However, some aspects may need to be negotiated—as is especially evident, for instance, at international meetings of curriculum scholars. Some aspects can be manipulated by, for example, introducing a common text or other artifact to focus attentions, which is a point that

that is embodied in activities such as academic conferences and preparation of academic publications.

None of this is to say that all members of a complex unity must "be on the same page" in terms of purpose, intentions, expectation, and so on. In fact, the vibrancy of complex unities arises in the mix of its redundant and its diverse elements—or, in systemic terms, the sources of its stability and its creativity. The harmonious co-existence of these elements is not strictly dictated by the system itself, but is better understood in terms of a function of the system-in-context. Minimal redundancy among (i.e., high specialization of) agents is most valuable in relatively stable settings, but it can be associated with a loss of robustness and, hence, presents a risk of poor adaptability if the context were to become volatile. For instance, wide-scale extinctions are often linked to overspecialization (more precisely, over-speciation) and consequent inability to adapt to new conditions. Similarly, factories that are organized around highly specialized micro-tasks can be very efficient, but very difficult to update or upgrade in the face of changing consumer demands. On the flip side, maximum redundancy (i.e., highly interchangeable agents, and therefore low specialization) is more appropriate in more volatile situations. Increased redundancy can also engender decreased adaptability, however. Taken to an extreme, a reduction in internal diversity can diminish a system's capacity to respond quickly and intelligently, simply because it lacks a sufficient range of diverse responses. In such cases, even minor perturbations can trigger the collapse of a system. On these counts, it bears mention that projects such as the internationalization of curriculum studies stand out as powerful examples of how and why one must seek out redundancy while promoting diversity. In a knowledge-producing system, these elements must co-exist in productive tension. (By way of more familiar and more accessible examples, the juxtaposition of varied voices around common themes in discussions of curriculum serve as provocative examples of the necessary simultaneity of diversity and redundancy. See, e.g., Pinar, 1999; Pinar, Reynolds, Slattery, & Taubman, 1995).

With regard to the internal dynamics of a collective learning system, it goes without saying that agents must be able to affect one another's activities. Clearly, neighbors that come together in a grander unity must communicate. However, what is not so obvious is what might constitute a *neighbor* in the context of a knowledge-producing community such as a research collective, an academic community, a classroom grouping, or even an individual's psyche. In our own ongoing efforts to interpret and prompt complex activity around educational topics, we have come to realize that the neighbors in knowledge-oriented communities are not physical bodies or social groupings. That is, although undeniably important, personal and group interactions for their own sake may not be as vital or as useful as is commonly assumed. Rather, *the neighbors that must interact* with one another are ideas, hunches, queries, and other manners of representation.

We recognize that there are dangers with the phrasing of the previous sentence. The claim that notions can "interact" might be interpreted as invoking a knowledge-as-object metaphor or as ascribing intentions to ideas. However, we understand knowledge in terms of potentials to action—necessarily dynamic, even volatile, subject to continuous revisions as the knowing agent integrates/embodies new experiences. The principle that we are developing here is more about the importance of activating these potentials in the hope that they might trigger others and, in the process, be blended into more sophisticated possibilities. One need only look to the academic world for many examples of these sorts of mechanisms, including conferences, seminars, journals, hallway interactions, visiting professorships, and wiki spaces, to mention only a few. A prominent metaphor that is used to point to such interactive structures is that of the conversation, foregrounding the contingent and engaged nature of the phenomenon. Unfortunately, a more descriptive English vocabulary for this manner of

ideational interaction has not yet emerged, hence our reliance on the somewhat troublesome, but nonetheless productive, notions of bumping, colliding, and juxtaposition of ideas.

A perhaps surprising implication here is that the critical point is that mechanisms be in place to ensure that ideas will stumble across one another, *not* that there must be a particular sort of organizational structure in a social collective. Small group meetings, round-table discussions, face-to-face interactions, and so on may be no more effective than large conventions, straight rows, and text-mediated exchanges. Indeed, in some instances, the latter structures can be considerably more effective. To restate this vital point, then, complexity thinking explicates the importance of neighbor interactions, but offers little generalizable advice on means to accomplish the meeting and blending of ideas. Teachers and educational researchers must make provision for the representation and interaction of ideas, but the means of doing so must be considered on a case-by-case basis, contingent on the particular issues, contexts, and participants involved. Notable trends in these regards include Web 2.0 (i.e., social networking applications, wiki-spaces, etc.; see Watts, 2004), collective "lesson study" protocols (Fernandez & Yoshida, 2004), and current movement toward "participatory" educational structures (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006).

Our experience is that one of the first lessons of enabling neighboring interactions is that one must relinquish any desire to control the structure and outcomes of the collective, following an important conclusion of complexity research (Kelly, 1994). Consistent with such unities as brains, anthills, cities, and ecosystems, control in a knowledge-producing collective must be understood as decentralized, arising in localized activities.

Note that in this discussion of knowledge-producing systems, just as "neighbors" is used to refer to ideas, "control" has to do with emergent conceptual possibilities. We are in no way suggesting that teachers, educational researchers, or curriculum scholars should abandon their responsibilities for organizing physical structures and spaces. Rather, we are talking about the development of interpretive reach, and that may entail rather rigid constraints on the physical system (as we discuss in the next section). The point is simply that *interpretive* possibilities (as opposed to physical conditions) cannot be managed. To impose a singular or centralized authority would be to extinguish the potential of the collective as a knowledge-producer.

In the context of this discussion of education, it might seem that an immediate implication of this condition of complex emergence is that the teacher-centered classroom and the researcher-led study group are inherently problematic. Such may well be the case, at least insofar as the desire to achieve preset objectives, but the conclusion is not fully justified. In fact, the condition of decentralized control also serves to problematize the constructs of student-centered classrooms and participant-driven research. This condition of complex emergence compels us to question an assumption that underlies arguments for both teacher/researcher-centeredness and student/participant-centeredness—namely, that the locus of learning is the individual. Learning occurs on other levels as well, and to appreciate this point one must be clear on the nature of the complex unities that might be desired in educational collectives. For us, these complex unities are shared ideas, insights, projects, concepts, and understandings that collectively constitute the group's *body* of knowledge. To underscore this point, the goal is not interpersonal collectivity, but collective knowing, noting once again that a knowledge-producing system is not the same as the knowledge produced by the system.

This conception of shared/decentralized control prompts our attentions away from matters of a leader's actions and toward consensual domains of authority. Within a structure-determined complex system, external authorities cannot impose, but merely condition or occasion possibilities. The system itself "decides" what is and is not acceptable.

Pragmatically speaking, with regard to shared/distributed work or understandings, the upshot is that a person should never strive to position herself or himself (or a text or other figurehead) as the final authority on matters of appropriate or correct action. Structures can and should be in place to allow students to participate in these decisions. For us, then, an important element in effective educational and research practices is the capacity to disperse control around matters of intention, interpretation, and appropriateness.

The four conditions that we have presented—that is, diversity, redundancy, neighbor interactions, and decentralized control—are just part of a longer list that is subject to ongoing revision (Johnson, 2001; Kelly, 1994). Complexity researchers have identified many others, including:

- negative feedback loops (mechanisms to keep systems in check, so that aspects do not spiral out of control);
- positive feedback loops (means to amplify specific qualities or dynamics that may be of use to the system);
- the possibility of dying (given the interdependency of agents, a significant rupture in their interactivity—such as a shift in the relational web arising from the failure or departure of an agent—presents the possibility of cascading failure and catastrophic collapse of the system);
- memory (complex unities embody their histories and identities, so an inability to preserve relevant information will precipitate a collapse of the system);
- stability under perturbations (although existing far from equilibrium, the patterns of activity and interactivity that constitute a system must have some measure of stability);
- reproductive instability (there must be room for "error"—that is, for the emergence of variations on relatively stable patterns—if a system is going to be adaptable).

We could go on but will suffice it to say that our basis for selection of the conditions discussed in this article is the extent to which the educator or educational researcher can affect or tinker. For instance, we might readily occasion the expression of diverse understandings in a research collective or a classroom. However, by contrast, it is not (yet) clear to us how we might tinker with negative and positive feedback loops. For those, and the others listed above, we rely on conditions that are already present and well developed in human social systems, but that tend to operate on biological and/or tacit levels.

On the constant need to restructure structures

Given the idiosyncratic characters, recursively elaborative, and ever-divergent possibilities of complex phenomena, accounts of complexity-informed research can never be offered as events to be replicated or even held up as models. At best, they can serve as illustrations, not exemplars. Indeed, we ourselves have failed in efforts to "replicate" studies in different settings, in large part because of inabilities to accommodate to the particularities of varied contexts. Encouraged by the fecundity of specific projects, we have on occasion misinterpreted or failed to perceive the ambiguities that arise between settings and, in the process, assumed a coherence (or the possibility of a coherence) that simply was not there.

In retrospect, in these instances, we failed to attend to the four conditions discussed in this article. Yet even if we had, there was no guarantee that a similar richness would have been achieved. Complexity cannot be scripted or managed into existence. However, it can sometimes be occasioned. The critical issue developed in this article is that such occasioning

is contingent not only on the appropriate conditions being in place, but for attentions to be oriented toward the appropriate level(s) of complex activity.

Or, phrased somewhat differently, an education that is understood in complexity terms cannot be conceived in terms of preparation for the future. Rather it must be construed in terms of participation in the creation of possible futures. Educational research, framed complexly, must also be interpreted as participatory—meaning that (following Jenkins et al., 2006), there are opportunities for expression and engagement, there is support for creating and sharing creations, there is some type of teaching so the most experienced can mentor new members, members believe their contributions matter, and members feel social connection with one another.

In this way, complexity theory offers an alternative to the longstanding tendency among educational researchers to import frames and foci from other domains. Complexity research does not allow such unidirectional borrowing. Rather, there is an expectation of participation in the emergence and evolution of insights. One does not "apply" complexity principles; one takes part in their articulation and elaboration. In this sense, we would argue, complexity theory can be properly construed as an educational theory.

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