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Conceptualizing Debates in Learning and Educational Research: Toward a Complex Systems Conceptual Framework of Learning

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This article proposes a conceptual framework of learning based on perspectives and methodologies being employed in the study of complex physical and social systems to inform educational research. We argue that the contexts in which learning occurs are complex systems with elements or agents at different levels—including neuronal, cognitive, intrapersonal, interpersonal, cultural—in which there are feedback interactions within and across levels of the systems so that collective properties arise (i.e., emerge) from the behaviors of the parts, often with properties that are not individually exhibited by those parts. We analyze the long-running cognitive versus situative learning debate and propose that a *complex systems conceptual framework of learning* (CSCFL) provides a principled way to achieve a theoretical rapprochement. We conclude with a consideration of more general implications of the CSCFL for educational research.

There are various perspectives from which to ground systematic inquiry into *learning*, which, of course, is the central enterprise in educational research. Discussions of these perspectives tend to argue for the primacy of a specific locus of theory and philosophy that in turn grounds various research agendas generally intended to validate, enhance, or challenge particular perspectives.

In fields that study learning and education, there have been important debates or "fault lines" (diSessa, 2006) about theory and methods. For example, there has been ongoing vigorous debate of theoretical import about the primacy of cognitive (Anderson, Reder, & Simon, 1996) and situative (Greeno, 1997) perspectives about learning, as well as cultural historical activity theory (CHAT; Engeström, Miettinen, & Punamäki, 1999; Nardi, 1996). We are perhaps on the verge of another distinct theoretical and empirical perspective about learning that is emerging from the neurosciences. There are already appeals to assigning primacy for theory and research about learning to this field over cognitive and sociocultural perspectives; however, for a critical discussion, see Bruer (2006).

Unfortunately, some of these debates related to theory and methodologies in the study of learning and educational research have been persisting for decades. This inability of the field to reconcile or vindicate one camp or another is a serious issue. For researchers interested in studying how people learn, this has meant "communities of practice" in educational research that have fractured into cognitive, situated, CHAT, and more recently neuroscience "silos" that

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are theoretically and methodologically isolated from each other or, perhaps worse, that simply ignore each other.

In a field of active research, it is critical that we raise and investigate the right kinds of questions (Greeno, 1997). In this article, we use one specific debate in the field—cognitive versus situative perspectives—as a conceptual case study from which to anchor consideration of questions and investigations over the past quarter of a century. We discuss this debate further next, but in this introduction we suggest that although research from the cognitive and situative camps in the learning sciences was useful, the collective impact related to this debate was not as productive as it could have been. Each side articulated its position in terms of different theories, methodologies, and associated studies, and through these means, important differences in interpreting the meaning of learning, knowledge, expertise, and competence were identified. By and large, however, the major issues separating these two camps were not resolved (Derry & Steinkuehler, 2003) and, as reflected in the recent *Educational Psychologist* special issue (Turner & Nolen, 2015), seem to persist to this day.

With this article we try to move debate about theory and methodology in the learning sciences and educational research forward, from analysis to synthesis, through the use of conceptual perspectives and methods from the study of complex systems. At this point in time, we are not sure a comprehensive complex systems theory of cognition may be articulated. However, we believe that current complexity perspectives might function best to inform a *conceptual framework* from which to view current and perhaps future theories of learning in terms of shared processes and conceptual dimensions. In this article, we discuss our initial steps at articulating such a conceptual framework for applications both to the cognitive-situative debate and to other issues in learning and educational research.

The article is organized into five main sections. First we provide an overview of complex systems and complexity, and second we propose an initial set of components for a *complex systems conceptual framework of learning* (CSCFL). In the third section, we briefly describe the cognitive-situative debate in the literature. The fourth section is the central section of the article in which we discuss how CSCFL provides a principled reconceptualization and rapprochement of the cognitive-situative debate and related issues in the field. The article concludes with suggestions for future research involving the CSCFL and implications for the field of educational research more generally.

FOUNDATIONS: COMPLEX SYSTEMS AND CURRENT INFLUENCE ON LEARNING RESEARCH

We now provide an overview of views about complex systems constructs that are foundational to the CSCFL we articulate later in the article. We also discuss ways in which complexity conceptual perspectives have been influencing research on learning to date.

What Is Complexity?

Scientific study of complex systems—sometimes referred to as *complexity*—over the past three decades has lead to insights about the world that classical approaches tended to over simplify or to ignore.[1] Briefly, complex systems are networks of individual *components or agents* that interact with each other and their environment often based on simple rules such neurons firing to activate or inhibit other neurons, ants foraging for food, or individuals buying stocks. *Feedback interactions* within and across levels of the system result in *self-organization*, such as the flocking formation of individual birds that are trying to stay together, but not fly too closely, and generally try to fly in the same direction. Complex systems often exhibit *sensitivity to initial conditions* (i.e., chaos), which can be amplified by feedback and result in nonlinear and probabilistic behavior in a system, such as the impact of the El Niño effect in the South Pacific on global weather patterns. Another key conceptual perspective of complexity is *emergence*,[2] which is when complex collective properties emerge from the behaviors of the parts, often with properties that are not exhibited by those parts. For example, in a traffic system, there are the interactions of cars (i.e., agents) generally moving *forward* as they speed up or slow down from which a traffic jam may *emerge* at a macrolevel of the traffic system, and which (once it emerges) propagates *backward* despite the forward movement of the microlevel behaviors of the cars. Examples of complex systems include the adaptation of white blood cells to invading bacteria, emotional and cognitive brain behaviors out of the interaction of individual neurons, dynamic equilibrium in ecosystems out of individual predator–prey interactions, segregation patterns in cities out of individual choices in places to live, and so on.

The complexity conceptual perspectives in the previous paragraph are sufficient to produce self-organizing systems "in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior" (Mitchell, 2009, p. 13). This is in fact one definition of complexity, which although broadly

[1]Readers interested in further information about the field of complex systems should consult Mitchell (2009) for a general discussion and Bar-Yam (2003) for a more technically oriented treatment of major constructs and conceptual perspectives.

[2]As we discuss further next, the construct of *emergence* is a central one in the study of complex systems (Bar-Yam, 2003; Gell-Mann, 1994; Holland, 1995; Kauffman, 1995; Mitchell, 2009). Briefly, emergence may be defined as interactions of elements or agents at a microlevel of a system that lead to the formation of patterns or properties at a macrolevel of the system that differ in key ways from those at the microsystem level.

useful, focuses on the behavior of the overall system ("complex collective behavior").

Given our interest in learning, there are also important conceptual perspectives about *complex adaptive systems* that let us understand how living organisms change or evolve as part of their interactions with other organisms and/or a changing environment.[3] Holland (2006) proposed that complex systems "involve many components that adapt or learn as they interact" (p. 1), which places the focus on the behaviors of the individual elements or *agents* making up the system. Holland further argued there are important features of complex systems, of which we believe three are the most relevant for this article: (a) *parallelism*, (b) *conditional action*, and (c) *adaptation and evolution*. First, parallelism refers to the simultaneous interaction of many agents in a complex system through sending and receiving signals. For example, in the brain, multiple nerve cell interactions occur via signals the excite or inhibit other nerve cells, whereas numerous biological cells typically interact via protein signals that provide positive and negative feedback in reaction cascades and cycles. Second, conditional action refers to agent actions typically in response to signals that have been received. Conditional actions are often described or modeled in terms of IF/THEN structures or rules: IF a certain signal is received, THEN execute or act in a certain way. Often relatively simple rules can be used to define agents in an environment that through the parallelism referred to above can yield very complex system behaviors. Third, of relevance to understanding learning, adaptation and evolution is perhaps the most important feature. Simply put, the agents in a complex system change over time. Examples of agents changing are replete in the world of living things, such as the genotypic changes that express as the phenotypic variety of the biological world, as well as the changes in the social world in what people learn.

In this section we have thus far provided an overview of two major perspectives about complexity, one stressing complex collective behavior and the other stressing how individual components or agents in a complex system can adapt and learn from their interactions. Are these incommensurable perspectives? We believe not.

The study of complex systems may be metaphorically viewed as not being about a "forest" or about "trees," but rather "forest-trees" (Bar-Yam, 2003). By this, Bar-Yam suggested that the principled theoretical oscillation or shifting of perspectives can yield insights into dynamics of importance across different levels of a complex system. The theoretical juxtaposition of complexity as "complex collective behavior" with individual agents adapting as they interact with other agents and their environment exemplifies, of course, *emergence*, which is perhaps *the* central construct of complexity conceptual perspectives. In the balance of this article, we consider the applicability of complexity perspectives more specifically for issues in the study of learning and in educational psychology and the learning sciences more generally.

[3]In the literature, a distinction is often made between *complex adaptive systems*, in which adaptation at the level of system components occurs over time such as changes in the genetic information in living organisms, and nonadaptive complex systems such as tornados or stars where individual atoms do not change. Given our interests in learning and educational systems, we do not make this distinction, and simply refer to *complex systems*.

Complexity and Emergence in Learning Research

Given that complex systems perspectives have been of value in research in other fields of scientific inquiry, in this section we consider how selected complexity ideas are now being incorporated into educational research. There has been a shift in the learning sciences and related fields of educational research over the past decade from earlier studies on students learning concepts *about* complex systems to the application of perspectives about complex physical and social systems for *conducting* studies of learning (for an overview, see Jacobson & Wilensky, 2006). One indication of this latter trend is reflected in the use of complexity concepts by researchers who are studying learning (e.g., Kapur, Voiklis, & Kinzer, 2005). For example, Bereiter and Scardamalia (2005) argued that

> as complex systems concepts such as self-organization and emergence make their way into mainstream educational psychology, it becomes increasingly apparent that there are no simple causal explanations for anything in this field. In general, what comes out of a sociocognitive process cannot be explained or fully predicted by what goes into it. Creative works, understanding, and cognitive development are all examples of complex structures *emerging* [italics added] from the interaction of simpler components (Sawyer, 1999, 2004). Learning itself, at both neural and knowledge levels, has emergent properties (Pribram & King, 1996). (p. 707)

This interest in complexity conceptual perspectives such as self-organization and emergence of Bereiter and Scardamalia is also shared by other learning and cognitive scientists (e.g.,Clancey, 2008; Goldstone, 2006; Kapur, Hung, Jacobson, Voiklis, & Victor, 2007; McClelland, 2010).

In this article, however, we do not just view complex systems concepts as being useful conceptual compliments in mainstream educational psychology and learning research. Rather, we view complexity conceptual perspectives as being *fundamental* to theories of learning.

We regard learning not as something that *is*—such as receiving instruction or acquiring knowledge—but rather, as something that *emerges* (Jacobson & Kapur, 2012). We define individual learning as *changes in human cognitive processes involved with the encoding and the capacity to manipulate and engage with symbolic representations, formalisms, and sociocultural practices that emerge from interactions with a variety* *complex systems* (Clancey, 2008) *an individual may experience over time that lead to enhanced performance in intellectual, physical, and affective realms of life*. We believe this definition aligns with the two main perspectives about complexity just discussed: complex collective behaviors (i.e., symbolic representations and formalisms, sociocultural practices) and individual agents in a complex system adapting and learning from their interactions (i.e., changes in individual cognitive processes).

If complex systems conceptual perspectives are fundamental for defining learning and the articulation of learning theories, then what are some specific implications of such a view? We now turn our attention to issues of theory in the study of learning.

COMPLEX SYSTEMS CONCEPTUAL FRAMEWORK OF LEARNING: AN INITIAL OUTLINE

In this section, we provide an initial outline of a CSCFL. What might be the value of such a conceptual framework? At a basic level, we hope this framework will provide concepts for describing what form theories of learning should take, specifying conceptual requirements of what they should describe, and identifying gaps in conceptual areas of theoretical import.

As previously mentioned, at this time there is not a general "theory" of complex systems. Rather, the study of complex physical, biological, and social systems by multidisciplinary fields has been providing a framework of conceptual perspectives, principles, and methods (e.g., emergence, self-organization, sensitivity to initial conditions) that might function to generate or to inform specific theories of relevance to understanding particular types of physical systems (Jacobson & Wilensky, 2006).

Drawing from our discussion about complexity and emergence in the previous section, the simple but fundamental claim we make in the CSCFL is that any theory of learning must be able to account for learning in terms of centrally important properties and characteristics of complex systems. At the core of the CSCFL is that *any theory of learning needs to account for the emergent nature of*

TABLE 1
Components of the Complex Systems Conceptual Framework for Learning With Examples

Complex Systems Focus Areas	*Complex Systems Conceptual Perspectives*	*Complex Systems Example*	*Learning or Educational Example*
Complex Collective Behaviors in System			
	Agents or elements in system	Ants foraging for food	Neurons in brain Students in classroom
	Self-organization	Birds flocking	P-prims forming coordination classes Children forming groups on playground
	System levels	Microlevel of chemical interactions, macrolevel of chemical system equilibrium	Individual student cognition, collaborative learning activities Vygotskian learning from interpersonal interactions that are internalized
	Sensitivity to initial conditions and nonlinearity	Butterfly effect	Gap in academic performance of low and high socioeconomic status children increases from kindergarten to high school Cognitive activation in initial learning influences subsequent learning
	Emergence	Classic "V" formation of flocking of individual birds	Collaborative interactions of students leading to convergence in problem solutions Emergence of conceptual understanding in conceptual change, "aha" moments
Behaviors of Individual Agents in System			
	Parallelism	Numerous biological cells typically interact via variety of protean signals	Numerous brain cells activated during problem-solving tasks Collaborative learning activities
	Conditional actions	If a wolf is hungry and sees a sheep, then wolf tried to eat the sheep	If a student is engaged, then greater persistence and subsequent learning
	Adaptation and evolution	Wing coloration of peppered moth changed (evolved) from mainly whitish/mottled to mainly darkish brown from pre- to postindustrial age Great Britain	Young children often have "flat earth" mental models, primary-age children often have synthetic "hollow earth" mental models, and older students have "globe earth" mental models.

human learning, as well as other important complexity conceptual perspectives that are shown in Table 1.

We suggest that there are two primary complex systems focus areas: *complex collective behavior in a system* and *behaviors of individual agents in a system*. There are five key complex systems conceptual perspectives associated with collective behaviors of a system shown in Table 1 and three core conceptual perspectives of individual agent behaviors. The Complex Systems Conceptual Perspectives section provides a general explanation of these conceptual perspectives with references for further information about them, but in Table 1 we also provide learning or educational examples.

We recognize there is overlap across the conceptual perspectives in Table 1, as the construct of *parallelism* refers to *agents* but also combines *signaling* of the agents that may be quite complex or relatively simple. *Conditional actions* provides a further explication of agent behaviors in a complex adaptive system (which is what educational and learning systems are), with *adaptation/evolution* providing the complexity conceptual perspective for how agents change over time.

The CSCFL may be used in two main ways. First, it may provide conceptual help with the interpretation of empirical findings from learning research. Second, it may inform theory development or be useful in ascertaining the efficacy or gaps in specific theories of learning.

As an illustration of the use of CSCFL in learning research in the first manner, we reference a study by the second author (Kapur, Voiklis, & Kinzer, 2008) that investigated problem-solving convergence (i.e., *self-organization*) in online group discussions, where group members interact with each other (i.e., *parallelism*). Kapur et al. (2008) examined the collaborative problem-solving interactions and performance of 11th-grade online triads solving problems in Newtonian Kinematics. Specifically, by focusing on the dynamics between the two *system levels* (member or agent level and group level), they studied the evolution of a group-level (*collective*) behavior—problem-solving convergence—from the interactions between group members (*agents*). To model convergence (*a collective behavior*), they employed a Markov Walk to code each members' (*agents*) interaction in the group discussion. Accordingly, each members' contribution was conceptualized as a simple rule (or a *conditional action*) that moved the group's solution *toward* (positive contribution) or *away* (negative contribution) from a correct solution, or maintained the status quo. Analysis revealed that high-quality member contributions made earlier in a discussion had a greater positive impact on problem-solving convergence than those made later on (*sensitivity to initial conditions*). Likewise, low-quality member contributions made earlier in a discussion had a greater negative impact on problem-solving convergence than those made later on (*sensitivity to initial conditions*). In other words, the self-organization of groups into convergent or divergent regimes was highly sensitive to the early exchanges between the group members. Convergence or divergence tended to emerge early in the group discussion, often within the first 30%–40% of a group's discussion (*sensitivity to initial conditions*). Surprisingly, convergence or divergence achieved by the first 30%–40% of a group's discussion was sufficient to predict eventual group performance, as measured by the quality of the eventual solution they produced.

Overall, this study showed that a complex system such as a collaborative problem-solving group can be examined at two *system levels* to understand how the dynamics at the agent level give rise to collective behaviors at the group level, and how these collective behaviors, once they have emerged, influence subsequent interactions at the agent level. This study also showed that the relatively simple rules (i.e., *conditional actions*) could be used to model microlevel interactions to examine how groups *self-organize* into convergent or divergent problem-solving trajectories, the temporal *evolution* of these trajectories, and the predictive effects of settling into such trajectories has on eventual group performance.

In this short example, we see that seven of the eight core complex systems conceptual perspectives in the CSCFL were of relevance to understanding the empirical findings of this study. As this was a relatively short intervention, the data provided do not indicate if there was or was not longer term learning, which would have represented CSCFL *adaptation and evolution*.

COGNITIVE VERSUS SITUATIVE THEORIES: A DEBATE

We next consider a theoretical case study of the cognitive-situative debate from which to consider the relevance of analytics afforded by the CSCFL. First, a historical overview of the debate is provided, and in the subsequent section we consider this debate from the prism of the CSCFL.

We observe that situative perspectives are very important in contemporary educational psychology and learning research, as reflected in a recent special issue in this journal (Turner & Nolen, 2015). In terms of an early articulation of situative views, the seminal publication of Brown, Collins, and Duguid (1989) argued that knowledge should be viewed as situated, as being a "product of the activity, context, and culture in which it is developed and used" (p. 32). Such a perspective had important implications for schooling, which they believe has been narrowly concerned with the transfer of abstract and decontextualized formal concepts.

However, the cognitive science research upon which many of the key arguments for situated learning by Brown et al. (1989) was itself generating considerable debate. In 1993, a special issue of *Cognitive Science* pulled together nine papers that debated these two perspectives about the study of human cognition and how people think and act. In terms of relevance to educational issues, this debate was extended in many ways reflected in a series of articles in *Educational Researcher* in the middle 1990s to 2000 in which the focus shifts from considerations of thinking and acting to implications of cognitive versus situative perspectives for teaching and learning. Anderson et al.'s (1996) article characterized situated learning as a view that much of what students learn is specific ("situated") to the context in which it was learned, which implies that knowledge does not transfer between tasks and learning abstractions is of little value. They went on to provide a critique of the application of situated learning in mathematics education in particular, and they proposed that educational approaches based on cognitive research into learning processes may be more efficacious than those based on situated perspectives.

The following year, Greeno (1997) provided a response in which he argued that the main differences between situative and cognitive perspectives discussed byAnderson et al. (1996) were primarily due to underlying framing assumptions of these two perspectives. In the same issue of *Educational Researcher*, Anderson, Reder, and Simon (1997) wrote a rejoinder to Greeno in which they found a degree of agreement between the cognitive and situative positions on evidence for findings and a consensus on certain educational issues. They also agreed that Greeno raised a substantive issue as to "whether the more profitable research path is one that takes individual or social activity as the principal unit of theoretical focus" (p. 20). Not surprisingly, Anderson et al. (1997) ended their rejoinder with a robust assertion of the superiority of the cognitive information processing approach over a situative theoretical approach.

This debate broadened somewhat in an article by Cobb and Bowers (1999), who criticized the conflicts between cognitive and situative learning theories as being of primary interest to educational psychologists and not to educators involved with classroom-based learning design and research. Still, the detailed discussion of their research for studying learning of mathematics in classrooms primarily employed a situative analysis approach as they felt there was little theoretical utility in the cognitive perspective of Anderson et al. (1997) for understanding the "essence of individual and collective human activity" (Cobb & Bowers, 1999, p. 13).

There was one final joint article by the main authors of the respective perspectives of this debate (Anderson, Greeno, Reder, & Simon, 2000), which identified important areas of agreement:

> (a) Individual and social perspectives on activity are both fundamentally important in education; . . . (c) Situative and cognitive approaches can cast light on different aspects of the educational process, and both should be pursued vigorously; (d) Educational innovations should be informed by the available scientific knowledge base and should be evaluated and analyzed with rigorous research methods. (p. 11)

Further, they did *not* position cognitivism and situativity as competing theories but rather as perspectives that deal with different levels of analysis. They also acknowledged their respective theoretical research programs are incomplete but expressed optimism that someday they will be bridged.

However, despite the areas of similarity and agreement that "individual and social perspectives" are each important in education and in research programs, even after the Anderson et al. (2000) article, the field overall seems to have continued a polarized view of these respective perspectives or theories. For example, Derry and Steinkuehler (2003) critically reviewed the literature related to cognitive and situative theories. They proposed that cognitive theory regards cognition as symbolic computation and broadly includes perspectives of *sociocognitive* theoreticians such as Piaget, as well as others summarized by Anderson et al. (1996). The situative perspective according to Derry and Steinkuehler embraces a family of social science theories including situated cognition, sociocultural theory, distributed cognition, and activity theory. Derry and Steinkuehler proposed a "pragmatist view" of the cognitive-situative debate, as they commented that many researchers and designers working in classroom environments were fusing points of view from the cognitive and situative perspectives. However, they also noted that a well-defined theory between these two communities of educational practice had not been proposed, which we believe is still true today. They further speculated that perspectives about complex systems might provide a superior viewpoint for theorizing. We concur.

THE COGNITIVE-SITUATIVE DEBATE THROUGH THE CSCFL PRISM

The CSCFL can be used to provide a theoretical reframing of the cognitive-situative debate. In terms of the Complex Systems Focus Areas of the CSCFL (see Table 1), the situative perspective primarily theorizes about *complex collective behaviors* associated with "social and ecological interaction as its basis and builds towards a more comprehensive theory by developing increasingly detailed analyses of information structures in the contents of people's interactions" (Greeno, 1997, p. 5). In our analysis, complexity conceptual perspectives associated with situative theory include *agents* (e.g., people and their interactions in terms of information structures), *conditional actions* (e.g., social norms and values influencing individual behaviors), and emphasis on *macrolevel system* features (e.g., social and ecological dynamics). However, situative theory does not seem to directly include CSCFL concepts such as *self-organization, sensitivity to initial conditions and nonlinearity*, or the key complexity construct of *emergence*.

Let us now apply the CSCFL to cognitive theory, which we analyze as primarily theorizing about the *behaviors of* *individual agents*, as well as including conceptual concepts from *complex collective behaviors* such as *microlevel* of a system. Other conceptual perspectives include *agents* (e.g., people) who have internal cognitive processes, *parallelism* such as cognitive structures forming from the interaction and signaling of multiple brain cells, *self-organization* (e.g., diSessa's, 1993, notion of p-prims forming coordination classes), *conditional actions* (e.g., student persistence, learning that is conditional on student engagement), and *adaptation and evolution* in terms of the changing of a student's internal conceptual structures over time. However, cognitive theory—like situative theory—does not directly include CSCFL concepts such as *sensitivity to initial conditions*, *nonlinearity*, or *emergence*.

Is there any significance to the lack of theoretical attention to the CSCFL conceptual perspectives of sensitivity to initial conditions and nonlinearity and emergence, or to the different levels of system focus—macrolevel for situativity and microlevel for cognition? We believe the lack of attention to emergence is a critical omission for both of these theories.

In fact, emergence in complex systems is often discussed in relation to *levels*. It is important to understand in a system of interest that *all* of the levels at any point in time are causally involved in interactions with the "environment" of an agent, synchronously, and that it does not make sense to assign primacy to a particular level in a complex system, that is, to identify the "main" or the "most basic" level. As an example of emergence in the context of learning, we refer to the preceding example of the Kapur et al. (2008) study that investigated how students engaged in online group discussions converged in their problem-solving solutions. Viewing the convergence that the students achieved in their interactions is not really understandable from the microlevel of individual cognition, nor is it understandable just from a collective or group macrolevel. It is better understood, we argue, by using the CSCFL in terms of constructs such as behaviors of individual agents, self-organization, and sensitivity to initial conditions that led to the emergence of convergence in the collective student responses, some of which that were correct and some incorrect.

As previously discussed, in the cognitive-situative debate in the 1990s, there was a clear advocacy of theoretical primacy for one perspective or the other that then relegated the other perspective to secondary importance. For cognitive advocates, individual cognition was the fundamental level and social contexts was viewed as an additional component (Vera & Simon, 1993), whereas situative advocates regarded the level of social and ecological interactions as theoretically primary and individual cognition as secondary (Greeno, 1997).

However, primacy of levels is problematic. That learning takes placed on multiple levels is probably not a seriously contested issue. Based on current theorizing, we can distinguish at least four levels on which learning is being conceptualized and researched: evolutionary processes, neuro-physiological processes, cognitive processes, and situated and sociocultural processes. Between each of these levels, emergent relations can be posited. For instance, the physiology of learning can be seen as emergent from evolutionary processes (Levels 1–2) and so can the relation between evolution and cognition (Levels 1–3).

The CSCFL has particular explanatory power for understanding key dynamics of these four levels in that complex systems perspectives *do not specify a priority relation for a particular level of a system*. This is a consequence of a related complex systems construct: the property of *near-independence of levels*[4] as being mechanistically dependent but nonreductionist. This means that each level is ontologically real and governed by its own set of causal mechanisms, constrained or influenced, but not determined, by the respective lower or higher across-level feedback interactions. Thus, notions of "primacy" of a level are problematic; straightforward reductionism in the form of explaining a higher level away as purely epiphenomenal is impossible.

A current theoretical view of a "basic" level (e.g., evolutionary biology perhaps, or cognitive processes) is not to be interpreted as foundational in the sense that all learning phenomena can in principle if not in practice be reduced to it. Although a tightly coupled lower level will *constrain* what can happen on the next level(s), it will not *determine* it. For example, the movement of a pen during writing has to obey the laws of physics, but what is written is not determined by physics. To explain writing, psychological (e.g., motivational) and/or cultural concepts (e.g., genre requirements) and levels of analyses need to be mobilized. From the CSCFL perspective, the existence of near-independent hierarchical levels does not raise questions about the primacy of a particular level (as is the case in the cognitive-situative debate) but rather raises questions about the nature of across level interactions and emergent properties.

In closing, we have tried to demonstrate how the CSCFL may be utilized to examine theories of learning in terms of attention to key conceptual perspectives that have been articulated in the study of complex physical and social systems. That a number of theoretical components of both situative and cognitive theories of learning do align with several key CSCFL conceptual perspectives is not surprising; after all, considerable theorizing and empirical work has been done in these areas for over a quarter of a century.

[4]According to Simon (1999), most complex systems in biology and human organizations have a hierarchical structure of "boxes-within-boxes arrangement of subsystems and sub-subsystems" that a "much higher frequency and intensity of interaction takes place between components belonging to a single sub-system than between components belonging to different sub-systems; and this principle holds for all levels of the hierarchy" (p. 8). Simon refers to this property as "near-decomposability"; however, we prefer the term "near-independence of levels."

However, we believe that the theoretical contribution of the CSCFL is it provides a perspective that can help us understand key differences between theoretical camps such as the cognitive-situative debate. More important, the CSCFL also helped identify major omissions in both theories such as sensitivity to initial conditions and nonlinearity and emergence. These omissions, in our view, limit cognitive and situative theories for informing understandings related to within and across levels dynamics of a system of learning that would account for emergent properties at the macrolevel, as well as the constraining interactions on microlevel agent behaviors once emergent properties come into existence. We leave for future work a more specifically articulated theory of learning informed (we hope) by conceptual perspectives such as those in the CSCFL.

LOOKING FORWARD

Before concluding our advocacy for a CSCFL, we first reflect on the oft-referred-to story of an individual who stops to ask a drunk at night who is prowling around on hands and knees underneath a streetlight, "What are you doing?" The drunk replies, "I'm hunting for my glasses." "But sir, they are not here; where did you lose them?" the stranger asks. "Over in the dark alley," says the drunk," but I can only see here."

In educational and learning sciences research, our "streetlights" are our theories and methodologies, so that the cognitive versus situative debate might metaphorically be regarded as two different streetlights. We argue in this article that viewing learning as emergence locates this phenomenon, at least partly, in the dark alley, hence our interests in new complexity-grounded theoretical constructs and methodologies that are being used to study complex physical and social systems (Goldstone, 2006; Jacobson & Wilensky, 2006). It is to be expected, of course, that new theoretical perspectives will invariably tend to generate more questions than answers. We both encourage and welcome this process, with hope that answers from perspectives we suggest from the CSCFL might answer at least some claims for right questions.

In the history of the physical sciences, new theories, such as Einstein's general theory of relativity that accounted for the precession of the perihelion of the orbit of Mercury and, more recently, gravitational waves, helped direct empirical research in physics to make important new discoveries that were inconsistent with earlier theories. We hope our nascent CSCFL might provide conceptual perspectives that reconceptualize issues such as the long-standing cognitive-situative debate in educational research, and for educational researchers to critically engage future debates. For example, it seems that the learning researchers are in for another "foundational" debate, this time around the importance of neuroscience (and to a lesser extent evolutionary biology) to "really" explain learning. From the perspective of the CSCFL, what we might call the new debate between the *neurosciences* and *the current learning sciences and educational psychology status quo* is in danger of repeating mistakes made in the earlier cognitive-situative arguments, such as a view of learning as an essentially a linear phenomenon, assuming primacy of the level of neuronal interactions over cognitive, situated, and CHAT levels, and—perhaps most important—failing to theoretically account for emergence in complex systems of learning.

Overall, we hope principled theoretical considerations of learning as an emergent phenomenon in complex neural, cognitive, situative, social, and cultural systems will yield critically important insights of central relevance to our field that might not otherwise be possible with current perspectives and approaches. In addition, viewing the environments in which learning occurs as complex systems provides educational and learning researchers with powerful conceptual perspectives and methodological tools (e.g., computer modeling; for a discussion, see Jacobson & Kapur, 2012) that are also being used by scientists in other areas of research. That there may be synergies of theory and methods between researchers in our field with scientists in other fields has the potential to enable cross-disciplinary research, as well as opportunities to more directly link findings from other fields to issues being explored by educational researchers and vice versa. We conclude humble and mindful of Einstein's famous admonition—"everything must be made as simple as possible, but not simpler"—as we articulate these first steps of a complex systems conceptual framework of learning.

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