Title
Complex Systems and the Cognitive Sciences: Potential for Pervasive Theoretical and Research Implications?

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Complex Systems and the Cognitive Sciences: Potential for Pervasive Theoretical and Research Implications?

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The primary goal of this symposium is to build upon arguments made in a recent Special Issue of the *Journal of the Learning Sciences* that research in the physical and social sciences related to the study of complex systems has theoretical, methodological, and research implications for the interdisciplinary fields of the cognitive and learning sciences, as well as for curriculum in terms of 21st century knowledge students will increasingly need to understand. The presentations in this symposium represent current perspectives related to these themes, with three primarily research based presentations and two data driven, computational modeling, and theoretical presentations. It is hope that the presentations in this session in conjunction with the discussant critique and audience comments may explore the potential centrality of complexity perspectives for theory, methods, and research in the cognitive and learning sciences.

Complex Systems In Cognitive Science: A Universal Acid?

Michael J. Jacobson

The multi-disciplinary study of complex systems in the physical and social sciences over the past quarter of a century has led to the articulation of important new conceptual perspectives and methodologies that are of value both to researchers in these fields as well as to professionals, policy makers, and citizens who must deal with challenging social and global problems in the 21st century. This presentation will: (a) argue for the importance of learning these ideas at the pre-college and college levels; (b) discuss research suggesting that there are significant cognitive challenges inherent in learning complex systems knowledge; and (c) consider ways that concepts and methodologies from the study of complex systems raise important issues of theoretical and methodological centrality in the fields related to the cognitive and learning sciences. Also, this talk provides a background for issues that will be considered in other presentations in this session.

Learning to See Complex Systems

Robert L. Goldstone

A complex systems perspective offers the promise of unifying increasingly fragmented scientific communities. If students can learn the principles underlying complex systems and recognize when they are applicable, then they should be able to transfer what they have learned to widely dissimilar domains, one of the greatest unsolved challenges for education. We will report on the results from a series of laboratory experiments exploring transfer of complex systems principles by undergraduate students. These experiments manipulate several design aspects of the computer simulations that are used to instantiate the principles: the graphical concreteness/idealization of the simulation elements, the specificity of the words describing elements, and the amount of contextualizing information or experience given to ground the simulations. Given these experiments and our experience using these simulations, we suggest that the most effective way to promote cross-domain transfer is to get learners to automatically see new situations using perceptual processes that have been adapted to previous situations, rather than relying on generalization from equations or abstract schemas.

Teaching a Stand-Alone Module: Emergence for Understanding Science Concepts

Micki Chi

The purpose of this project is to develop a stand-alone, domain-general module to improve understanding of highly misconceived science concepts. This domain-general approach, henceforth called the *schema approach,* focuses on the structure underlying a class of science concepts and phenomena. This structure is the idea of *emergence*, related to notions of complex dynamic systems (Goldstone, 2006; Jacobson, 2006). Our assumption, based on prior analyses, is that students are ignorant of emergence, and the absence of this structure leads to misconceptions. Hence, we propose an intervention in the form of a brief, self-contained module that introduces such a structure, followed by subsequent instruction on specific concepts that relate to this module. We will report on the content of such a module and some preliminary learning results using such a module, to see if it can help students achieve greater learning, deeper understanding, and more successful transfer to concepts across science domains.

The Complexity of Education Research and Why We Like It

Dor Abrahamson

Agent-based modeling (ABM) is one of several methodologies used by science and social science researchers studying complex phenomena. We have been using ABM, embodied in NetLogo (Wilensky, 1999), for engaging in research on scientific, cognitive, and sociological phenomena germane to education theory and practice. ABM has gradually come to constitute a common perspective on different aspects and levels of our practice: (a) Initially, ABM framed analyses of STEM/social-science content, such that we designed and researched learning environments for student ABM inquiry; (b) We then analyzed behavioral patterns of learners engaged in participatory simulation activity (such that the students themselves were agents in the learning community; Colella, Borovoy, & Resnick, 1998; Wilensky & Stroup, 1999; and individual cognition was modeled as emergent, Minsky, 1985, Blikstein, Abrahamson, & Wilensky, 2006); and (c) recently, we have explored the potential of ABM to shed light on theoretical debates in theory-of-learning research. We are particularly excited by a study of student participation patterns in demographically diverse classrooms engaged in collaborative construction projects. These agent-based models, which express complexity-studies theory of social interaction (Axelrod, 1997), are juxtaposed on the computer screen with videotaped data from real classrooms. Our presentation will include "running" agent-based models alongside real data. We will conclude with a discussion of possible methodological limitations and epistemological issues inherent to the modeling-and-simulation mode of inquiry.

Scale-Free Networks and Human Knowledge Representation

Manu Kapur

In the cognitive sciences, networks (e.g., associative, semantic, propositional, etc.) have a long-standing history of being used to understand human knowledge representation (HKR). Emerging research in complex adaptive systems points to yet another network—a scale-free network—as a candidate for understanding HKR. This presentation will: (a) describe what a scale-free network model entails, including what it means to hypothesize a scale-free network model of HKR, (b) contrast the existing network models with a scale-free network model of HKR, and (c) review emerging empirical evidence from diverse fields of language, creativity, problem-solving, etc. that supports the hypothesis. In doing so, the presentation will explore the intriguing theoretical possibility that scale-free networks that naturally emerge in many complex adaptive systems may also underlie/resemble that of HKR.

Discussant

William J. Clancey

Complexity is not a theory, but a pervasive 20thc scientific shift in analytical perspective—from reductionism to how patterns and structures form and interact. A challenge to cognitive science is to rework models of distributed cognition to capture the non-local control, regulation layers, and coupling in biological systems. Might we view conceptualization as a complex system of neural, psychological, social, and ecological organizations of cognition?