Rising Above? Implications of Complexity for Theories of Learning

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Abstract: A recent article—*Conceptualizing Debates in Learning and Educational Research: Toward a Complex Systems Conceptual Framework of Learning*—analyzed the long-running cognitive versus situative learning debate and proposes that a Complex Systems Conceptual Framework of Learning (CSCFL) could provide a principled way to achieve a theoretical rapprochement. In this session, we bring together major educational and learning theoreticians for cognitive, situative, embodied, and socio-cultural perspectives to consider, debate, and to perhaps (or not) "rise above" currently engaged major issues, debates, and disagreements that fundamentally influence educational research in a wide range of areas.

Session summary

The main objective of this session is bring together major educational and learning theoreticians who generally conduct research from cognitive, situative, embodied, and socio-cultural theoretical perspectives to discuss and consider a *Complex Systems Conceptual Framework of Learning* (CSCFL) proposed by Jacobson, Kapur, and Reimann (2016). Their article argues 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," such as *complex collective behavior in a system* (e.g., system levels, nonlinearity, emergence) and *behaviors of individual agents in a system* (e.g., parallelism, conditional actions, adaptation and evolution). The CSCFL is then used to analyze the cognitive-situative debate, noting "a number of theoretical components of both situative and cognitive theories of learning do align with several key CSCFL conceptual perspectives" but also that "the CSCFL … helped identify major omissions in both theories such as *sensitivity to initial conditions and nonlinearity* and *emergence*. (p. 217)" Their article notes the applicability of the CSCFL for new "debates" about the potential primacy (or not) of neuro-science over cognitive and situative perspectives and concludes with the hope that "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 (p. 217)."

The organizers of this session hope that bringing together these distinguished researchers for "principled theoretical considerations of learning" will help answer the question posed in the title of this session: Is a complex systems conceptual framework fundamental to theories of learning? If yes, then why; if no, then why not.

Scholarly or scientific significance

This session is significant because it will open a dialogue and exchange of ideas and perspectives by a distinguished group of researchers whose work has been influenced by different theoretical perspectives who will consider potential merits and limitations of the CSCFL proposed by Jacobson et al. (2016). Further, through their interactions, the participants and the audience can perhaps identify or articulate ways to advance thinking in the field of educational research broadly construed about issues of fundamental theoretical importance.

Structure of the session

This 90-minute session opened with comments by the Chair (5 minutes), followed by the five presentations (10 minutes each). The participants were asked to consider three main points in their presentations: (a) provide a brief overview of their main theoretical orientation, (b) discuss how their theorizing has informed their main research activities, (c) consider if the CSCFL (or some complexity-based variation of it) *might* or *might not* provide insights not otherwise possible with current theoretical perspectives in educational and learning research. The Discussant then provided comments for 10 minutes followed by 25 minutes for small group discussions and audience questions.

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Methodological applications of the CSCFL: Quantitative and qualitative methods meet agent-based modeling

Michael J. Jacobson, The University of Sydney; Manu Kapur, ETH Zurich; and Peter Reimann, The University of Sydney

Our respective research activities have generally employed a range of quantitative methods (e.g., experimental and quasi-experimental designs, discourse analysis, data mining) and we have also used conceptual aspects of the CSCFL in our research, such as Kapur, Voiklis, and Kinzer (2007) (e.g., *sensitivity to initial conditions*) and Jacobson et al. (2017) (e.g., *system levels, emergence*). In this presentation, we propose to extend the applicability of the CSCFL from considerations of theory to another key issue in the field: *methodologies for doing research and their suitability for studying learning as an emergent phenomenon.* Our reading of the educational research literatures associated with cognitive and situative empirical studies is that researchers in these "camps" typically use different methodologies. In general, we find papers based on cognitive perspectives tend to employ quantitative research methods, whereas situative researchers tend to use qualitative and descriptive methods (i.e., design research), with some use of mixed methods (of course, we recognize there are exceptions).

Why is this important? There is an issue about whether either quantitative or qualitative methods are sufficient for explaining the *emergence of learning*. That is, we need to ascertain if and how these methods can deal with critically important facets of complex systems of learning such as *emergence,* the *dialectical co-existence of linearity and nonlinearity*, and issues of *scale and hierarchical levels of systems*. Unfortunately for quantitative approaches generally used in education, its major tools involve mathematical modeling (e.g., differential equations, statistical models) that are primarily (but not exclusively) *linear* tools to break a system into its components or parts, study the parts individually, and then add the parts together to form the whole. Unfortunately, emergent phenomena have important characteristics that are *nonlinear* and that cannot be analyzed by "adding up the parts" (Jacobson & Kapur, 2012). There also are limitations for using qualitative approaches to understand the emergence of learning. While qualitative methods have certain advantages over quantitative approaches (Firestone, 1097), we argue qualitative techniques still have certain limitations for understanding learning as an emergent phenomena. For example, the spatial-temporal scale of learning as it emerges from complex neural, cognitive, social, and cultural systems poses challenges for qualitative approaches that must focus on a humanly-manageable portion of the entire space and time over which a learning or educational phenomenon unfolds.

From the perspective of the CSCFL, a significant way to address these inherent limitations in the existing quantitative and qualitative approaches used in educational research is a *hybrid approach* that incorporates methodologies being used to study other types of complex physical and social systems (Jacobson & Kapur, 2012). We expect that research informed by the CSCFL would likely employ computer modeling methodologies such as agent-based modeling (ABM) and network models that are increasingly being used in the natural sciences (Holland, 1995; Mitchell, 2009) as well as in social science areas (Epstein, 2006), including economics (Arthur, Durlauf, & Lane, 1997), sociology (Elder-Vass, 2010), and organizational science (Carley, 2002). The symposium presentation discussed research employing such hybrid methods (Abrahamson, Blikstein, & Wilensky, 2007; Kapur, Voiklis, & Kinzer, 2008; Levin & Datnow, 2012; Maroulis et al., 2010), and considered challenges and issues for using such approaches.

Connecting the unit of analysis in learning research

Sten Ludvigsen, University of Oslo

Over the last three decades, the conceptualization of the phenomena of learning and cognition has been a hot topic. In the award-winning paper published in *Educational Psychologist*, "Conceptualizing Debates in Learning and Educational Research: Towards a Complex Systems Conceptual Framework of Learning," a new conceptual turn is suggested (Jacobson, Kapur, & Reimann, 2016). I will take a socio-genetic (cultural) perspective on the problems of complexity raised in this symposium. "Socio-genesis" means understanding the multiple layers involved in activities when analyzing human learning. We thus need to avoid the fragmentation of the learning sciences in separate units of analysis and levels of descriptions. When the analysis of learning takes a starting point that involves social interaction and artifacts in complex systems, the question of connecting layers and the unit of analysis becomes urgent.

In most stances in learning theory, the unit of analysis mainly focuses exclusively on the individual within an environment. The socio-genetic perspective, however, provides an analytic stance that encompasses three layers (social interaction, the individual in interaction, and social practices) that we must view as interdependent (Ludvigsen & Arnseth, 2017).

When taking socio-genesis as a premise, understanding learning starts with an analysis of micro-interactions. The study of micro-interactions implies a detailed analysis or measurement of how students engage in reasoning and problem-solving in specific knowledge domains or in themes that cross areas of disciplinary knowledge. Social interaction is crucial because it is here that history, tools, and human action come together and mutually shape one another. This is the first layer in the analysis. The second layer focuses explicitly on how students make their cognitive, social, and emotional competences relevant through a series of actions in interaction with others (process analysis). This layer gives insight into how students manage to interact with others and into their mastery of specific forms of knowledge. The third layer focuses on the institutional and historic dimensions that create affordances and constraints for students' actions (the social practices). Institutions will always involve a degree of complexity and emerging phenomena that requires a broader historical and institutional analysis using a variety of methods.

The socio-genetic (cultural) stance includes the complexity that creates the foundation for learning and the kinds of concepts that the field needs to progress. It makes it possible to work with different types of analysis rather than with only one analytic layer. We need to recognize that multiple layers influence participant's processes and performance. This will give us a more robust, nuanced, and sophisticated understanding of human learning and cognition. In modern society, this often involves the use of computational artifacts.

The cognitive-situative divide and the perspective of a complex systems framework

Stella Vosniadou, College of Education, Psychology and Social Work, Flinders University

I am a cognitive developmental psychologist who works in the area of conceptual development and conceptual change. From my perspective, I find that the attempt on the part of the situated perspective to capture the dynamic and social nature of learning is in the right direction. However, I also consider that treating knowledge entirely as a process "an activity that takes place among individuals, the tools and artifacts that they use, and the communities and practices in which they participate" (Greeno et al., 1996, p. 20) is problematic, particularly for a theory of learning that needs to explain phenomena like conceptual change. Nevertheless, I believe that it is possible to soften the boundaries between the cognitive and situative perspectives and to allow for conceptual change, by accepting that humans are processors of symbolic structures and that knowledge is something that can be acquired and change, while also accepting that this acquisition happens through participation in socio-cultural activities (Vosniadou, 2007). In other words, there is no need to see a conflict between learning as acquisition as opposed to learning as participation if we consider that knowledge structures exist in the form of symbolic representations, but also accept that these symbolic representations were acquired through participation in socio-cultural activities. Conceptual change in this system is the result of a complex process of interaction between individuals and the world through a rich variety of mediated symbolic structures. Further, it is proposed that teaching for conceptual change cannot rely on the implicit methods of cognitive apprenticeship, but must aim towards developing in students the metaconceptual awareness required for explicit and intentional belief revision through the appropriate use of socio-culturally based practices and carefully designed research-based curricula.

Jacobson, Kapur and Reimann (2016) propose a conceptual framework of learning based on the study of complex systems—physical or social—arguing that such a framework can provide a theoretical rapprochement to the cognitive versus situative learning debate. Although I am not sure that the complex systems framework can indeed provide such a rapprochement, I do agree that learning occurs in complex social and cultural contexts and that a perspective which examines it as an emergent phenomenon brings to the study of learning and of conceptual change theoretical constructs and methodologies that have the potential to yield new and innovative insights.

The art and science of impact: Unlocking human potential from a dynamic systems perspective

Sasha Barab, Anna Arici, and Earl Aguilera, Arizona State University

We are arguing for a paradigm shift in the ways we think about unlocking human potential, one that sees content as fundamentally linked to practice, people as having rich potential, and technology as one component of an empowered ecosystem.

While unlocking human potential is clearly a complex endeavor, many of us working to innovate and positively impact this area have been operating under the wrong paradigm for creating sustainable growth. We have created an artificial divide among the *content* what one needs to know, *the context* in which it has value, and how it transforms *the person* who is doing the learning (Engeström, 1987). Quite problematically, we have allowed for human capacity to be treated as a "commodity" that, in the form of knowledge, can be converted into some "technological fix" and transmitted into the mind of a passive learner.

From this starting point, too many efforts have failed to recruit the everyday individuals whose potential we are invested in catalyzing (Engeström & Saninno, 2010). Rather, many approaches to learning position them as objects to be changed (problems to be solved) rather than as change agents (problem-solvers) themselves, passionately invested in expanding their own ability to do great things (Barab, Cherkes-Julkowski, Swenson et al., 1999). When a design is focused on content transmission with an assumption of fixed and isolated minds, we devalue the capabilities learners bring to the process and undermine those we are working to empower.

In contrast, we are arguing for an ecological and optimistic perspective of learning that considers one's motivation for learning as a key component of the complex learning ecosystem. More importantly, clearly there are problems that are amenable to "technological fixes" (Sarewitz & Nelson, 2008) in which the solution is bound up within the technology itself; for example, the use of antibiotics to fight an infection. However, even in the most direct causal relationships of biochemistry, there is still a wide variability in how each person will respond to the same treatment, with many contextual factors and complex interactions involved in the successful administering of medication (e.g., getting a correct diagnosis, affording the cost, finishing the treatment, experiencing side effects, or over-prescribing that leads to drug resistance).

Naturally, these variations are even less predictable when applying innovations to complex issues like unlocking human potential. It is here, that complexity theory is essential to conceptualizing how one leverages innovation for impact. In creating innovations to address literacy, discrimination, health, or unlocking human potential more generally it is unlikely that any designed product alone, whether a pill or a technology, will prove sufficient for achieving meaningful impact; too many other factors interplay. Instead, in this presentation we will draw from complexity theory to offer a complicated and more optimistic view of how we leverage innovation to help people grow.

When we shift from overly deterministic and mechanistic perspectives of how innovation can support human growth we begin to look not at technological fixes but at empowered ecosystems (Barab & Arici, in press). Empowered ecosystems involve interpretive space where learners, technologies, and enabling resources can come together to produce solutions. They have elements of dynamic systems, especially in terms of the solutions living in the dynamic interactions among the various components, but we will also argue for the investment of the learner. Any intervention that does not leave room for interpretive space and allow for agency is unlikely to cultivate the necessary energy for growth to emerge (Engeström & Saninno, 2010).

We view complexity theory as essential to accounting for the success of the platform revolution where the focus of the innovation is to connect consumers and producers who bring and create value—in contrast to pipeline solutions that disseminate value (Choudary, Van Alstyne, & Parker, 2016; Van Alstyne, Parker, & Choudary, 2016). Pipeline technologies are based on linear cause-effect relations with the solution residing within one component and the innovation focused on most effectively dispensing these solutions. A platform perspective, coupled with complexity theory, positions "solutions" as distributed among multiple interacting components with the goal being to empower and catalyze dynamics (see Figure 1). In this way, we argue that innovations for impact should be conceptualized, designed, and researched as complex ecosystems—not isolated technologies.

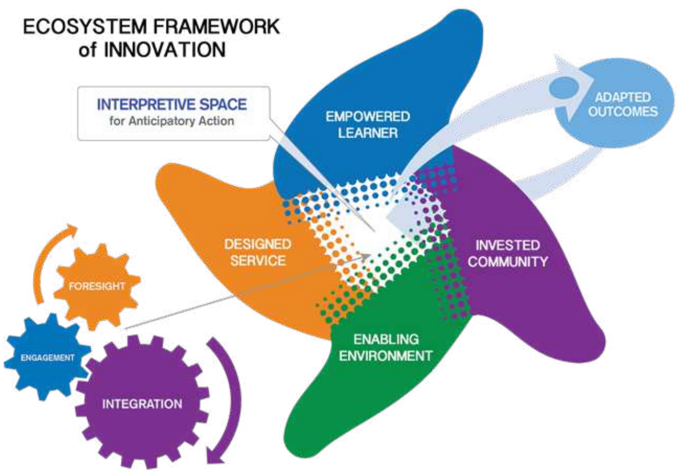

Figure 1. An Ecosystem-Based Framework for Characterizing Innovation for Impact.

Do the merits of the complex systems conceptual framework of learning extend to design-for-learning guidelines?

Mitchell J. Nathan, University of Wisconsin

My scholarship in STEM education is influenced by a theoretical perspective that characterizes learning and development as emergent phenomena that arise from interactions between processes that operate at a wide range of scales (Figure 2). In addition to this theoretical perspective, methodologically, I distinguish between systemic and elemental approaches to learning research (Nathan & Sawyer, 2016). Elemental approaches assume aspects (such as context) can be "factored out" and analyzed independently (Greeno & Engeström, 2016). Systemic approaches reject this "factoring assumption."

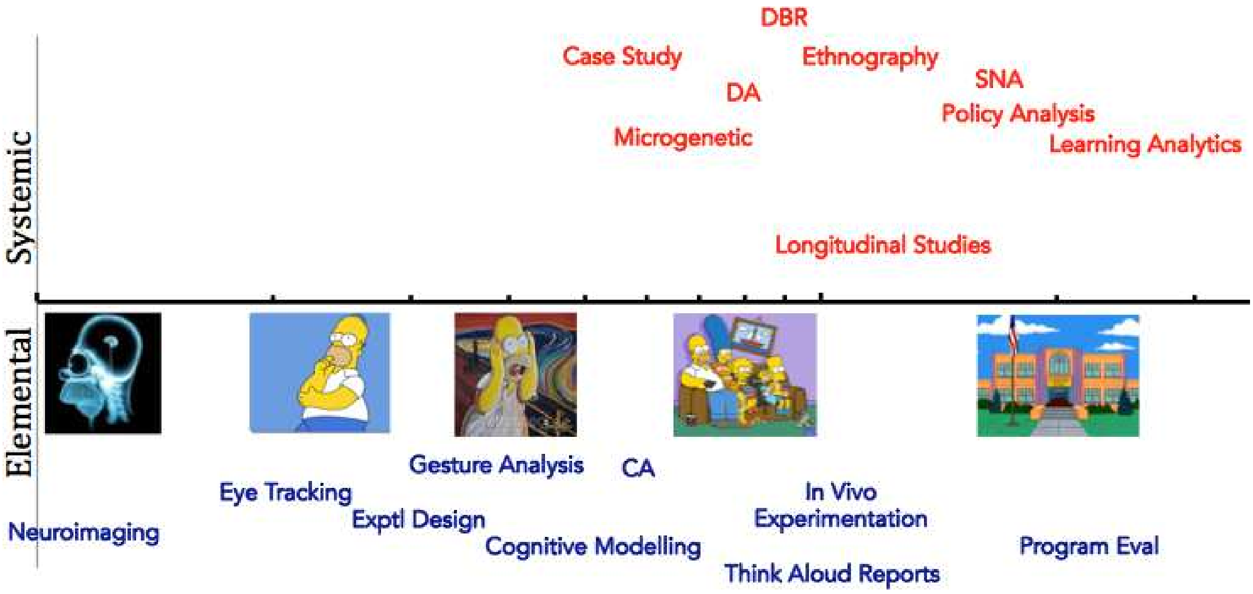

Figure 2. A Log10 time scale of human learning. Systemic (above) and elemental (below) research methods are placed in approximate scale.

For example, I am intrigued by ways that fine-grained processes of embodiment operating at the level of neural, perceptual, and motoric systems, contribute to, or *supervene on*, complex cognitive processes such as conceptual learning, inference making, teaching, and educational policies that operate at greater time scales (e.g., Nathan & Martinez, 2015; Nathan & Walkington, 2017). This also motivates my use of a systemic perspective on classroom learning by studying both learning/learners and teaching/teachers, and their interactions. These systemic studies of situated learning and instruction combine with elemental investigations into potential mediators of the complex behaviors of interest. Information from systemic and elemental studies each inform early stages of design based research on learning environments as experienced by teachers and students.

One central outcome is that teachers are highly responsive to students' in-the-moment learning needs, and that teachers and students each employ physical enactment of their thoughts, levels of cognitive development, and social communication along with spoken language to make sense of new ideas, be understood by one another, and manage the complexities of the environment to foster learning and engagement (Alibali et al., 2014; Nathan & Kim, 2009; Nathan et al, 2015). These studies demonstrate that much of what we know, as well as how we teach and communicate what we know (and what we think we know about what others know), is embodied, as exhibited by behaviors such as gesture and movement, the use of objects and space, and metaphors linking abstract ideas to concrete experiences. This seemingly formative role embodied processes have on complex cognitive behaviors has significant implications for learning environment design and for formative and summative assessment, which I would discuss during the presentation.

Fit of CSCFL

In my view, learning, and behavior more generally, is a complex system, with many processes and subsystems interacting dynamically to produce the emergent phenomena that we observe. My questions enter on *how* to use complex systems theory to advance our understanding of learning and produce effective learning environments.

First, we need to move beyond what Cognitive Science has achieved in defining and measuring initial conditions and constraints in areas such as attention, perception, and memory, to tackle the question of supervenience: How do the processes operating at different scales interact to produce observed and intended behaviors? Second, we must also acknowledge that studies of learning always under constrain the design guidelines needed to create and implement effective learning environments. I would push the panel to weigh in on whether and how CSCFL can bridge the design-for-learning question.

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