Special Issue: Proceedings of the Symposium on Complex Systems in Education: Questions, Methods and Implications for Practice, Held at the Conference on Complex Systems, Amsterdam, Netherlands, September 20, 2016

DIMITRIOS STAMOVLASIS
Aristotle University of Thessaloniki (Greece)

MATTHIJS KOOPMANS
Mercy College (USA)

The present special issue is yet one more collective endeavor in the area of educational research that demonstrates how the new science of complex dynamical systems could be applied in this domain. In social sciences, while the linear methodologies are, at the moment still the main stream, the appreciation of the new paradigm has already been growing, and a considerable body of research has been published recently in regular journals, special issues on complexity and edited book volumes. In physiology, behavioral sciences, economics and life sciences, complexity theory and nonlinear dynamics have been proven highly influential advancing the discipline. Education is no longer a late follower to those developments, but a privileged area where complex dynamical system (CDS) is by now an established paradigm.

Complexity theory has inspired researchers and scholars working in education and curriculum studies to approach their subject matter from a different angle, and ask different questions, focusing on the processes through which things come to be what they are. It has also changed traditional ways of thinking, in qualitative as well as quantitative research, perhaps setting the stage for a paradigm shift. The foundation of the new science has been based on empirical studies that implement concepts of CDS,

Complicity: An International Journal of Complexity and Education
Volume 14 (2017), Number 2 • pp. 1-6

including quantitative nonlinear statistical methods that are uniquely designed to study dynamical phenomena. In addition, theories are built by posting and testing new research hypotheses about education and its processes related to teaching and learning.

In addition, methodological tools offer the prospect for real-time analysis of teacher-student interactions (e.g. State Space Grids (SSG, Pennings & Mainhard, 2016), or time-series analysis with the implementation of nonlinear tools (Koopmans, 2015). These are just a few examples.

The present issue adds to the current literature by presenting the cutting-edge contributions to a satellite symposium held at the Conference on Complex Systems held in Amsterdam, Netherlands in September, 2016. The presentations cover a wide range of topics, methods and analyses, within the nonlinear framework. They also use different local theories and to demonstrate the wide applicability of the CDS perspective.

Koponen, Kokkonen and Nousiainen, explore the conceptual change in physics education by means of computational modelling and attempt to understand the generic dynamics and the emergent features of learning phenomena. They discuss the formation of robust learning outcomes from the CDS viewpoint, considering students' conceptions as context dependent and multifaceted structures. In this analysis, the conceptual patterns appear to be robust in certain situations, but not in others. The computational modeling approach proposes that stability is arises dynamically and does not reflect rigid or static intuitive conceptions. The important message from this analysis is that it shows how context dependence, described by an epistemic landscape structure, might lead to the formation of stable states, which might be certain naïve mental models or misconceptions. These states could be viewed as the attractors of the system in a learning process, where the outcome appears as a progression of shifts from one state to another, giving thus the appearance of conceptual change as switches from one robust state to another. This theory suggests certain pedagogical approaches in designing tasks for learning physics concepts and related phenomena; i.e., teaching interventions start with the detection of the hypothetical mental models that resist to change, and then focus on altering them.

Stamovlasis presents a review of empirical investigations in science education research addressing the nonlinear dynamical hypothesis. The new paradigm of complexity and nonlinear dynamics offers better interpretations of empirical data and theoretical advances. Previous research has shown that besides linear modes of behavior, sudden transitions occur in cognitive performance modelled via catastrophe theory, using neo-Piagetian constructs as controls (Pascual-Leone, 1970). Thus, it was established that there are variables, which can act as bifurcation factors under the certain conditions, but not others. Beyond a critical value of the bifurcation factor, the state variable splits into two-attractor regions and the distribution of observations becomes bimodal. This bifurcation effect has been interpreted as inducing uncertainty and unpredictability in the system, which oscillates between two states entering the regime of chaos. Then in state variables such as learning outcomes and achievement, sudden transitions from success to failure (or vice versa) are expected. Empirical findings have revealed the bifurcation role of cognitive constructs, i.e., field dependence/independence, or motivational variables, such as performance avoidance goal orientation in learning processes, establishing therefore the merger between the local theories and CDS framework. Catastrophe theory is the appropriate framework for explaining unexpected phenomena associated with school failure, dropouts, illicit behaviors, sudden attitude change, and creativity.

Steenbeek and van Geert work towards understanding teaching and learning processes, seeking conceptual or/and statistical models to study these processes. By observing and recording such process, a conceptual model of intertwined learning-teaching processes is generated illustrating dynamic modeling as an approach to theory formation about teaching-learning processes. Notions, such as the evolution term, the timescale of interaction processes, state space as a perspective on teacher-student interaction dynamics, and the principle of agency, are invoked to describe teaching-learning processes in CDS terms; while time series analysis combined with other techniques, such as cluster analysis provide the empirical indexes to evaluate these iterative processes. It is emphasized that in order to study such dynamical process, one needs to make a great number of observations on a variety of timescales, from microgenetic to macrogenetic. The principle of agency is used to explain interaction dynamics in conjunction with the self-determination theory (Ryan & Deci, 2000) referring to three major human concerns, namely the desire for autonomy, for relatedness and for competence. This is an example of how local theories can be used and merged into the CDS framework and thus contributing to further theory building.

Pennings presents a study where complex dynamic systems theory and interpersonal theory (e.g., Kiesler, 1996) are combined to describe the teacher-student interactions. She describes the behavior of two teachers with different interpersonal styles using behavioral time-series. The focus is on looking at different steps in the analysis (Warner, 1998) and examining several aspects of time series at the general level and overall coordination. She investigates the presence of linear, quadratic and cubic trends in behavior, as well as the residual fluctuations, when studying the alignment between teacher and student interpersonal behavior. The interpretation of the findings is based on the principle of complementarity, which claims that teachers exhibit the tendency to react with complementarity to behavior of students. Results showed that the teacher-student interactions for the case of the teacher with the most desirable interpersonal style largely followed the complementarity principle, while this does not hold for the interactions of teachers with the less desirable interpersonal style. The ability to bring out this dependency on complementarity on interpersonal style illustrates the added value of CDS concepts and methods.

Koopmans contribution applied CDS framework at the school level, examining school attendance and drop-out, which traditionally are investigated via mean rates in specific schools and regions or socio-economic groups. Putting forth a different hypothesis, i.e. how stable those attendance rates are over time, leads to fostering a CDS view of school functioning and considering the temporal variation of school attendance, time series analysis proved to be the appropriate analytical tool. Investigating the temporal dimension of daily attendance and thereby exploring its stability, reveals some long term characteristics that would have remained hidden if conventional approaches were used. Specifically, self-similarity, meta-stability or pink noise and the impact of sudden departures from the central tendency of the series, are worth paying attention to. The nonlinear analysis suggests processes of self-organized criticality in daily high school attendance, which are lost if data is reported in terms of weekly or monthly average. The trajectories depicting the attendance over time might show turbulence, patterns that repeat in unpredictable ways, and unexpected departures of individual observations from the central tendency of the series. The statistical confirmation of such patterns adds to our knowledge and understanding of how attendance behaves over time and modelling sudden changes is an analytical tool suitable to address the impact of external factors affecting the internal regulation of the system. The above nonlinear analysis for such valuable data, suggests not only a paradigm shift appealing to researchers merely, but also a shift to ways of thinking for and approaching education as a system, appealing to teacher and policy makers.

Hiroki Sayama and his co-workers present an applied education project which addresses an important aspect of complexity, i.e., social networks, understanding their ontology, structure and dynamics (Watts & Strogatz 1998; Barabási & Albert 1999), and they use a social network approach attempting to specifically create rather than merely describe educational change. The concept of networks is a crucial framework in understanding complexity and has become ever-more relevant to people's everyday life. Examples of networks may include the internet, social media, financial systems, transportation networks, ecosystems, organizations, friendships, schools, classrooms, learning materials, brains, or immune systems. Every such system can be represented as a network, that is, as a discrete structure that consists of nodes and edges that connect the nodes. Nodes are vertices, entities, actors, or items, and edges are links, relationships, ties or connections. To disseminate knowledge about networks, the NetSciEd, Network Science and Education, was created and addresses the needs for resources, accessible materials curricula for teaching networks to students and/or to the general public. This presentation, informs literature for those attempts which have an instructive scope, rather than research and theoretical orientation, contributing though to preparing minds to apprehend the complexity of the reality and addressing an important need to bring the concepts of CDS into educational practice.

Ton Jörg presents a philosophical paper taking a radical complexity-inspired bottom-up approach which shows complexity as the fount of creativity and innovation. His ultimate aim is to redefine education within a complexity frame to start thinking about how complexity is actually generated in the real world. Inspired by Vygotsky's theory, a process-oriented bottom-up approach is presented, which opens new spaces of the possible in the educational process. It is claimed that a generative bottom-up process being linked with potential nonlinear bottom-up effects over time can form a generative causal framework. Focusing on this link between the new thinking in complexity and the causal, generative nature of complexity in the real world, this helps explain the ontological creativity of the entire world in general, but also human learning and development in particular.

Doris Fromberg fosters CDS to provide a novel account of child development referring to sudden transitions driven by the underlying nonlinear dynamical processes. She discusses phenomena related to the brain functioning, socio-dramatic play and relates them to meaningful early learning. The presentation starts with questions about how young children actually do learn, how they solve problems and how they develop self-regulation. The CDS perspective can help to better understand the generative process of early childhood play and learning in human development. Aspects of nonlinearity, such as sensitive dependence on initial conditions, the equivalence of different surface manifestations with underlying processes, dynamic phase transitions become critical elements of our understanding young children's play and learning.

The present issue is proud to present these innovative contributions. They are products of a continuously growing interest in Complex Dynamical Systems applied in educational research and their potential to transform the field. These studies illustrate that CDS can offer innovative pathways to inquiry, inspire new types of questions or hypotheses, and new ways of thinking. Thus, the work presented here contributes to an expanding research agenda concerning the application of CDS, offering a novel perspective on familiar educational phenomena.

References

Barabási, A.-L. & Albert, R. (1999). Emergence of scaling in random networks. Science, 286(5439), 509-512.

Chow, J. Y., Davids, K., Button, C. Shuttleworth, R., Renshaw, I., & Araujo, D. (2006). Nonlinear pedagogy: A constraints-led framework for under-standing emergence of game play and movement skills. Nonlinear Dynamics, Psychology and Life Sciences, 10, 71-102

Kiesler, D. J. (1996). Contemporary interpersonal theory and research. New York: Wiley.

Koopmans, M. (2015). A dynamical view of high school attendance: An assessment of short-term and long-term dependencies in five urban schools. Nonlinear Dynamics, Psychology and Life Sciences, 19, 65-80.

Pascual-Leone, J. (1970). A mathematical model for the transition rule in Piaget's developmental stages. Acta Psychologica, 32, 301-345.

Pennings, H. J. M., & Mainhard, T. (2016). Analyzing teacher-student interactions with state space grids. In M. Koopmans and D. Stamovlasis (Eds), Complex Dynamical Systems in Education: Concepts, Methods and Applications (pp. 233-271). Switzerland: Springer Academic Publishing.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist. 55: 68–78.

Steenbeek, H, & van Geert, P. (2013). The emergence of learning teaching of trajectories in education: a complex dynamic systems approach. Nonlinear Dynamics, Psychology and Life Sciences, 17, 233-267.

Stamovlasis, D. (2006). The nonlinear dynamic hypothesis in science education problem solving: A catastrophe theory approach. Nonlinear Dynamics, Psychology and Life Sciences, 10, 37-70.

Stamovlasis, D. (2011). Nonlinear dynamics and Neo-Piagetian Theories in Problem solving: Perspectives on a new Epistemology and Theory Development. Nonlinear Dynamics, Psychology and Life Science, 15, 145-173.

Stamovlasis, D., & Koopmans, M. (2014). Editorial Introduction: Education is a Dynamical System. Nonlinear Dynamics, Psychology and Life Science, 18(1), 1-5.

Watts, D. J. & Strogatz, S. H. (1998). Collective dynamics of 'small-world' networks. Nature, 393(6684), 440-442.

Warner, R. M. (1998). Spectral analysis of time-series data. New York: Guilford

About the Authors

Dimitrios Stamovlasis, PhD, is Assistant Professor of Research Methodology and Applied Statistics for Social Science at the Aristotle University. His research interest they focus on methodological and epistemological issues of contemporary social sciences, nonlinear dynamics, complexity, catastrophe theory, entropy, and related fields. Correspondence: stadi@auth.gr.

Matthijs Koopmans is an Associate Professor at Mercy College. His current research interests include the application of complex dynamical systems approaches to education, cause and effect relationships, and nonlinear time series. Correspondence: mkoopmans@mercy.edu