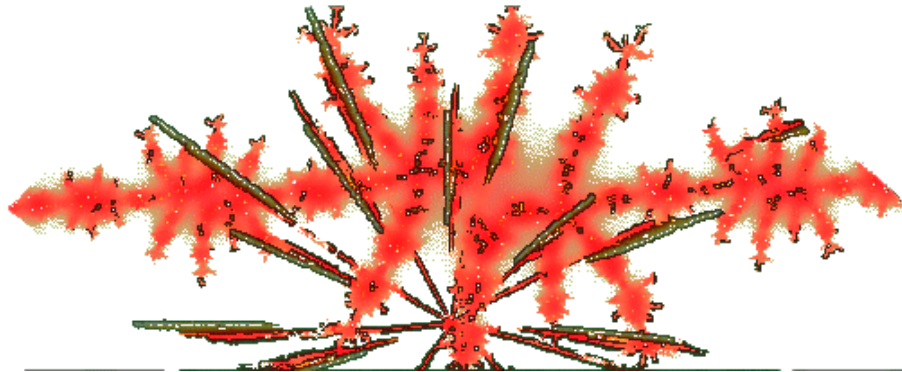


# Nonlinear Dynamics, Psychology and Life Sciences

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### **Nonlinear Change and the Black Box Problem in Educational Research**

Matthijs Koopmans, Mercy College, Dobbs Ferry, NY

*Abstract:* Although the nonlinear dynamical systems (NDS) paradigm has been highly influential in psychology, economics and the life sciences, its impact in the field of education has been disturbingly modest, particularly in the interface between research and policy, where linear cause and effect relationships are typically presumed when the impact of interventions and educational reform on the behavior of children and adults is measured. This reduction of the educational process to simple input – output relationships without examining the constituent changes in great detail produces significant gaps in our knowledge about the effectiveness of educational initiatives, an issue that has been acknowledged in the research literature as the ‘black box problem.’ This paper approaches the black box problem from an NDS perspective and proposes that investigating the self-organizing process in the educational system may help address these gaps.

**Key Words:** randomized control trial designs, self-organized criticality, black box problem, nonlinear change

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### **A Nonlinear Dynamical Systems Approach to Real-Time Teacher Behavior: Differences between Teachers**

Helena J. M. Pennings, Mieke Brekelmans, Theo Wubbels, Utrecht University, Anna C. van der Want, Eindhoven University of Technology, Luce C. A. Claessens, and Jan van Tartwijk, Utrecht University

*Abstract:* A positive teacher-student relationship is important for students’ motivation, students’ academic achievement, and teacher well-being. How the teacher-student relationship develops in real-time has hardly been studied. In the present study we explored real-time interpersonal behavior (micro-level) for teachers with different relatively stable patterns of interpersonal teacher behavior (macro-level), i.e., interpersonal profiles. Interpersonal profiles are considered indicative of the teacher-student relationship. Interpersonal teacher behavior was conceptualized using Interpersonal Theory in terms of (a blend of) Agency and Communion. We used a Nonlinear Dynamic Systems (NDS) approach to explore differences in content (attractors) and structure of changing behavior (variability) in real-time interpersonal teacher behavior using State Space Grid (SSG) analyses. We found the expected differences between teachers and correspondence between the location of the attractors in the SSG and the blend of Agency and Communion characterizing the teachers’ interpersonal profiles. Regarding structure, we found the expected higher variability in real-time behavior for teachers with interpersonal profiles characterized by lower levels of Agency and Communion. We concluded there is sufficient potential of NDS to differentiate between teachers in order to use a NDS approach in future research on the connection between teacher-student relationship and real-time teacher interpersonal behavior.

**Key Words:** real-time interpersonal teacher behavior, interpersonal theory, state space grid, nonlinear dynamic systems

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## **An Adaptive Process Model of Motor Learning: Insights for the Teaching of Motor Skills**

**Go Tani, Umberto Cesar Corrêa, Luciano Basso, Universidade de São Paulo, Brazil, Rodolfo Novellino Benda, Herbert Ugrinowitsch, Universidade Federal de Minas Gerais, and Koji Choshi, University of Hiroshima, Japan**

**Abstract:** This article presents an outline of a non-equilibrium model, in which motor learning is explained as a continuous process of stabilization and adaptation. The article also shows how propositions derived from this model have been tested, and discusses possible practical implications of some supporting evidence to the teaching of motor skills. The stabilization refers to a process of functional stabilization that is achieved through negative feedback mechanisms. Initially, inconsistent and incorrect responses are gradually reduced, leading to a spatial-temporal patterning of the action. The adaptation is one in which new skills are formed from the reorganization of those already acquired through the flexibility of the system, reorganization of the skill structure, or self-organization. In order to provide learners with competency for adaptation, teachers should (a) guide students to learn motor skills taking into account that the stabilization of performance is just a transitory state that must be dismantled to achieve higher levels of complexity; (b) be clear which parts (micro) compose the skills and how they interact in order to form the whole (macro); (c) manipulate the skills in terms of their temporal, spatial, and/or spatiotemporal dimensions; (d) organize practice initially in a constant way, and then in a varied regimen (random) when the motor skills involve requirements of time and force; and, inversely for motor skills with spatial demands; and (e), provide a moderate frequency of feedback.

**Key Words:** adaptation, complexity, non-equilibrium, teaching-learning, motor skill.

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## **Ought-Approach versus Ought-Avoidance: Nonlinear Effects on Arousal under Achievement Situations**

**Dimitrios Stamovlasis, Aristotle University of Thessaloniki, Greece, and Georgios D. Sideridis, Harvard Medical School, Boston, MA**

**Abstract:** The present study examines the dimensions of oughts under a nonlinear perspective. Ought-approach and ought-avoidance have been proposed as two different dimensions of oughts, which have an opposite effect on subjects' arousal level under achievement situation. The change in arousal level measured by heart rates per minute

(HRPM) was modeled as cusp catastrophe by implementing the two dimensions of oughts as the control parameters: the ought-approach as the asymmetry and the ought-avoidance as the bifurcation factor. The cusp model was proved by far superior from the three alternative linear models and provided the empirical evidence that the two dimensions of oughts are distinct and are associated with different processes. The ought-avoidance dimension being the bifurcation factor acts in a destructive manner by introducing nonlinearity and uncertainty in the self-regulation process (with regard to HRPM). The interpretation of the model is provided and implications are discussed.

**Key Words:** ought-approach, ought-avoidance, motivation, self-regulation, heart rate, nonlinear dynamics, cusp catastrophe, self-organization

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## **A Dynamic Nonlinear Model for Educational Systems: A Simulation Study for Primary Education**

**Porfirio Guevara, University of Graz, Graz, Austria, Luis López, INCAE Business School, Alajuela, Costa Rica, Alfred Posch, University of Graz, Graz, Austria, and Roy Zúñiga, INCAE Business School, Alajuela, Costa Rica**

**Abstract:** This article improves our understanding of the causal processes driving the dynamic behavior of education systems using a System Dynamics approach. The model presented here has three state variables: Population, Population in Primary School, and Primary School Graduates whose values are calibrated for the case of Nicaragua. It also includes nonlinear complex interactions between critical factors, e.g., the state of the economy, the state of the education system, and population literacy that affect the system's transition rates —intake, repetition, dropout, and promotion— which therefore influence the dynamics of schooling outcomes. These schooling outcomes in turn affect population literacy and economic progress in the country thus generating aggregate patterns that continuously change (and are changed by) the inputs that endogenously determine them, which could potentially explain why educational systems exhibit persistently good or bad outcomes. Simulation runs show a strong correspondence with observed data and additionally the model provides meaningful insights to guide policy making in educational reform, such as the ability to reveal the presence of “ghost students”. This paper concludes that complex dynamic systems modeling and simulation can facilitate forecasting of school system behavior and the detection of policy inconsistencies, something conventional modeling cannot do.

**Key Words:** feedback, complexity, nonlinearities, computer simulation, forecasting