Education as a Complex System: Implications for Educational Research and Policy

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Talk Outline

› Policy reflections
› Complexity and complex systems
› Education as a complex system
› New methodologies for studying educational systems
› Educational systems research and educational policy
› Challenges of learning about complex systems and implications
› Oxford English Dictionary
  - Etymology: < Middle French policie , pollicie government, political organization, the state (c1370),
  - A principle or course of action adopted or proposed as desirable, advantageous, or expedient; esp. one formally advocated by a government, political party, etc.
› Suggest policy is also about managing social problems and issues
› What complexity concepts and approaches might be of value in understanding educational policy problems and issues related to learning?
Video: Glimpses of Future Learning
Video Link: http://tinyurl.com/okg346p
Bereiter and Scardamalia (2005) observe:
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 [italics added].

Lemke and Sabelli (2008) further observe:
The education system is one of the most complex and challenging systems for research. Much as we know about cognitive aspects of learning, pedagogical strategies, and reform implementation, we currently lack the modeling capability needed to help practitioners and policymakers explore the potential impact of proposed interventions, since efforts in this area are still at a very preliminary stage of development.
Framework for Education as a Complex System
Framework for Educational Systems and Reform Initiatives (Lemke & Sabelli, 2008)

1. System definition
2. Structural analysis
3. Relationships among subsystems and levels
4. Drivers for change (not considered in this talk)
5. Modeling methods
1. System Definition (1)

› System elements and environmental dynamics
  - Institutions and social practices
  - Sources and users of information
  - Human and material resources

› Included elements must be tightly coupled and interdependent

› Students

› Learning contexts
  - Formal learning environments with teachers at schools and universities
  - Informal learning environments of science museums, mass media, print publishing, and increasingly, online Internet mediated sources

› Stakeholders in educational systems
  - School boards and trustees
  - Government education authorities
  - Research institutions and local communities
1. System Definition (2)

› Levels of organization
› Not simply control hierarchies of lines of authority
› Complexity levels:
  - Micro level interactions
  - Emergent patterns and processes at mezzo and macro levels of the system
› Information and material resources flow across adjacent and non-adjacent levels of an educational system
› Example:
  - One level, the individual grades of a student are sent to parents
  - Grades transformed and reorganized to extract relevant information higher system levels of the school, district, state, or country
2. Structural Analysis (1)

› Hierarchies of formal organizations (common in policy)
  - Individual students and teachers
  - Student groups and classrooms
  - Departments and schools
  - Districts, states or provinces
  - Entire national system

› Analysis of different *timescales of different system levels*
  - Milliseconds of neuronal synaptic interactions and cognitive processes
  - Minutes for individual students and student-teacher conversational interactions
  - Hours of the school day
  - Months of school terms
  - Year at a grade level
  - Years of primary, secondary, and tertiary education
  - Years and decades of policy implementations at national level
2. Structural Analysis (2)

› Exchange of information across timescales
  - Classroom activities over periods of minutes
  - Curriculum change processes occurring over periods of years

› Development of conceptual understandings
  - Learning events in classrooms or a laboratory
  - Experiences in hallways, cafeterias, and outside of school

› Development of long lasting identities, attitudes, and values over years
  - Occur in the context of networks of social interactions between peers in a class
  - Local communities and virtual social networks of online communities

› Once identities, attitudes, and values emerge, they influence decisions and actions adults might make in very short timescales of seconds, minutes, or hours

› Community problems and changing national priorities influence the overall agendas and programs of the larger educational system
3. Relationships among Subsystems and Levels (1)

› Of particular importance are the levels above and below a specific focal level of interest

› A teacher interested in implementing a new teaching approach might consider:
  - A level below—how students might respond
  - A level above—how the Principal might view the new approach

› More generally for educational systems
  - Next higher level of the organization might provide positive or negative feedback
  - Could enhance or constrain how the dynamics at the focal level unfold

› Similar manner, subsystems at a level lower might also provide feedback interactions that could influence the behaviors at the focal level
3. Relationships among Subsystems and Levels (2)

› Kinds of matter and information that are exchanged across subsystems and levels
  - Classrooms with computers, tables, and seating from the school administration
  - Aggregate school performance reports provided to policy makers

› These interactions across subsystems and levels might be tightly coupled,
  - School funding used to purchase computers
  - Linked to specific targets for school performance in reports or large-scale national or international educational assessments
Edward Lorenz at 2002 International Conference on Complex Systems:
- Climate is what you expect
- Weather is what you get

Dialectical co-existence of linearity and non-linearity (Jacobson & Kapur, 2012):

“The complexity of emergent behavior comes from the co-existence of linearity and non-linearity across and within multiple levels or scales of an open system. Indeed, because of this, complex systems exhibit seemingly opposing properties and behaviors: randomness and order, predictability (e.g., attractors, highly connected nodes or hubs) and unpredictability, coherence and incoherence, stability and instability, centralization and decentralization, and so on. It is not one or the other, it is both (Kauffman, 1995).”
Complexity and Methodologies for Studying Education
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› Complexity implications for
  - Academic research into how educational and learning systems function and behave
  - Policies regarding educational systems

› Connection between two areas
  Information flows available to policy makers are constrained by the types of methodologies that have been developed and validated by academic research

› Methodological approaches for educational research and science more generally
  - Qualitative
    - Phenomenological philosophical basis
    - Seeks to describe and to understand
  - Quantitative
    - Positivist philosophical basis
    - Seeks to establish causal or quasi-causal explanations
Are existing educational research methodologies sufficient for providing appropriate information and understandings of the dynamics of education viewed as a complex system?
No
Why?

› Major mathematical tools used in educational quantitative methods (e.g., statistical modeling)
  - Fundamentally tools for a linear system
  - Break a system into its components or parts
  - Study the parts individually
  - Add the parts together to form the whole

› However, emergent phenomena
  - Have nonlinear properties
  - Cannot be analyzed by “adding up the parts”
  - Patterns at the macro-level generally have different properties than the constituent parts at the micro-level of the system
Holland (1995): “Nonlinearities mean that our most useful tools for generalizing observations into theory—trend analysis, determination of equilibria, sample means, and so on—are badly blunted”
Nail in the Coffin?

- Quantitative and qualitative approaches limited to explaining and understanding what has already emerged (Epstein & Axtell, 1996)

- Example: Opinions, norms, convergence in group discussions emerge
  - Quantitative methods may be used to aggregate-level relationships
  - Qualitative methods may provide descriptions and understandings

- However, if one could unwind time
  - The same trajectory may not have unfolded even if one started with similar initial conditions (Kauffman, 1995)

- Understanding complex systems and emergent phenomenon
  - Not only the trajectory of evolution that actually unfolds
  - But also the possibility space of trajectories of evolution that could unfold
Quantitative and qualitative approaches place significant limitations on understandings of the possibility space over which complex educational systems may unfold.
New Methodologies for Studying Educational Complex Systems
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› Computational modeling and visualization approaches (Jacobson & Wilensky, 2006; Lemke & Sabelli, 2010)
  - Agent-based models (ABM)
  - Network analysis
› Do not replace quantitative or qualitative techniques
› Rather compliment them (Jacobson & Kapur, 2012)
› Computer modeling can provide research insights into
  - How micro-level behaviors of individuals or groups relate to emergent macro-level system wide phenomena
  - How emergent properties can then enhance or constrain micro-level behaviors
  - Possible states a system might progress into
› Envisioning possible futures of a focal point of interest in an educational system
Examples of Visualizations, Network Analysis, and ABMs for Educational Research

› Network analysis (Franks et al., 2008)
  - Identify boundaries of student social groups that emerge from interactions in local school contexts
  - Quantitative approaches would use a priori categorization of students as “scholars” or “athletes” common in effects-based research

› New tools for visualization of longitudinal network data
  - Analysis of across level interactions
  - Content analysis of students’ discourse to emergent outcomes of classroom discipline

› Another advantage of these techniques is that they can be applied to existing large-scale datasets
Quantitative and qualitative analysis provided inconclusive findings

ABM
- Students: small dots
- Dark red: high-poverty
- Dark green: low-poverty
- Circles: schools
- Circle size: academic performance

Model use
- Provided insights into systemic effects
- Identified approaches to minimize the transfer of top students by private schools where vouchers issued by the government that were used to pay for the private schooling
Implementing High School Reform: Multi-level Agent Based Modeling Interactions

› Simulate the influence of principal leadership on teachers, students, and district personnel in effective reforms (Levin & Datnow, 2012)
› Data driven decision making (DDDM)
  - Use data to guide a range of educational decisions
  - Different uses by principles and teachers
› Model shows across level feedback interactions
  - Green lines: positive feedback
  - Red lines: negative feedback
› Model fits qualitatively collected data
› Note: generalization is not possible with qualitative methodologies
Model Distillation: Minimal Non-linear Model of DDDM
Epistemic Challenge: Simple Explanations for Complexities of Learning?

1. Complexity-Complexity view:
   Complex systems such as the ones educational researchers study must have “complex” explanations

2. Simplicity-Simplicity view:
   Simple systems must have “simple” explanations

3. Simplicity-Complexity view:
   “The central task of a natural science is to make the wonderful commonplace: to show that complexity, correctly viewed, is only a mask for simplicity; to find pattern hidden in apparent chaos.” (Simon, 1996)

   › Common epistemic bias toward #1 and #2
   › Challenge for educational researchers and policy makers to accept #3
Challenges of Learning about Complex Systems and Implications
Why Complex Systems in Education? Gaps in Mainstream Education

› Complex systems knowledge the province of research and advance graduate students in a few scientific areas
› Little of the conceptual power and tools of complex systems in mainstream education
› Potential consequences:
  - **Educational gap** between current best understandings and analytical tools in the physical and social sciences
  - **Working knowledge gap** of professionals, policy makers, and an informed citizenry
› Policy challenge:

  *How to shorten the typical 20-30 year gap between new scientific understandings and integration into mainstream learning experiences?*
Research into High School Students Learning About the Scientific Complexity of Climate Change
Elicitation Phase
- Low structure
- Generate as many ideas as possible

Consolidation Phase: Teacher Led Intervention
- High structure
- Includes procedural consolidation

Assessment Phase
- Low structure
- Problem-solving questions
- Concept explanation
Conclusion

› Early days in the incorporation of complex systems and modeling approaches in educational research and policy
› Potential for these approaches to address limitations in conventional educational quantitative and qualitative research methodologies
› Need to foster broader understanding of complexity concepts and methods in formal education
  - Bring current scientific ideas into science education
  - Contribute to a better informed professionals and citizenry in modern democracies
› Potential alignment of research in the study of other complex physical and social systems areas and study of educational complex systems
› Potential for alignment of policy initiatives in common governmental areas, such as:
  - Economic to transportation systems
  - Social services and educational systems
Thank you!

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