Complex Systems View of Educational Policy Research

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Education researchers have struggled for decades with questions such as “why are troubled schools so difficult to improve?” or “why is the achievement gap so hard to close?” We argue here that conceptualizing schools and districts as complex adaptive systems, composed of many networked parts that give rise to emergent patterns through their interactions (1), holds promise for understanding such important problems. Although there has been considerable research on the use of complex systems ideas and methods to help students learn science content (2), only recently have researchers begun to apply these tools to issues of educational policy.

We roughly categorize existing education research into two categories, “mechanism-based” and “effects-based.” Mechanism-based studies include ethnographies, case studies, and laboratory experiments that focus on understanding individuals and their interactions inside schools. Such work has provided insight into the motivation and cognition of students, teachers, and school leaders, as well as how social phenomena unfold inside schools (3, 4). Effects-based research treats factors contributing to academic performance of schools as inputs that work together to yield a particular level of student achievement (5). By analyzing variation in quantitative observational data on inputs and outcomes (6), or through the execution of field experiments (7), effects-based research has increased our understanding of the relative importance of factors such as teacher-pupil ratio, family background, and teacher quality and has established effects (or lack thereof) of specific interventions designed to improve achievement.

What Works, How It Works
Despite of such successes, and as evidenced by the call for more “mixed-methods” designs (8), a key challenge facing education research is to integrate insights about “micro-level” processes with evidence about aggregate, “macro-level” outcomes that emerge from those processes. For example, suppose we have results of a well-executed experiment using a nationally representative sample of schools that indicates students in small classes perform better than those in large ones. Although it is tremendously helpful to know that, on average, students in small classes do better, this alone is not enough to fully understand what changes policy-makers and school leaders should implement.

One reason for this is the issue of heterogeneous treatment effects (9). If small class size mattered under certain conditions but not others, school leaders would need to understand what happened differently in some small classrooms that led to better student outcomes. Both mechanism- and effects-based research may be helpful here, examining differing contexts and how programs are implemented. But we still face the challenge of aligning micro-level accounts with “macro-level” outcomes that emerge from those processes. For example, suppose we have results of a well-executed experiment using a nationally representative sample of schools that indicates students in small classes perform better than those in large ones. Although it is tremendously helpful to know that, on average, students in small classes do better, this alone is not enough to fully understand what changes policy-makers and school leaders should implement.

Bridging the Gap
Applying a complex systems perspective to education research parallels the recent use of complex systems methods to model the spread of epidemics (14). Traditionally, one relied on (i) detailed case studies that traced social con-
create a new model that provides a more general framework for understanding complex systems. In particular, it allows for the representation of a system with multiple agents, each of whom has its own specific characteristics and behaviors. This new model is based on a network of social interactions, and it is capable of capturing the emergent properties of the system as a whole. The model is also able to simulate the effects of various policies and interventions on the system, allowing for a more nuanced understanding of the potential outcomes of different policy options.

The new model is a significant improvement over existing approaches to modeling complex systems, as it is able to capture the complexity of real-world systems in a more realistic and accurate way. It is also capable of providing insights into the potential outcomes of different policies and interventions, allowing for a more informed decision-making process.

The new model is currently being tested and validated in a variety of contexts, including social networks, economic systems, and biological ecosystems. The results of these tests are expected to provide a more accurate and comprehensive understanding of complex systems, and to inform the development of more effective policies and interventions.

References and Notes
2. On using complex systems principles to transfer knowledge between scientific domains, see (13); on the cognitive difficulties of understanding complex systems, see (14); and on understanding scientific phenomena by constructing agent-based models, see (10, 35).
11. In economics, “general equilibrium effects” refers to the coupling changes that occur as a result of a change in a focal market after supply and demand realign in related markets. Most effects-based research is done under the alternate assumption of “partial equilibrium,” which does not account for such feedback. See (13).
15. C. H. Henneke, J. E. Buring, Epidemiology in Medicine (Little, Brown, Boston, 1997).
20. A common line of analysis involves using measures of an individual’s location within a social network to test hypotheses about the role of social structure in determining his or her performance. For example, one can test whether the association between peer influence and student achievement is moderated by the extent to which a student’s friends are also friends with each other. See (23), and for a review outside of education, see (22).
27. U. Wilensky, NetLogo (CCL, Northwestern University, Evanston, IL, 1999); http://ccl.northwestern.edu/netlogo/.
30. Agents in CGE models are assumed to be constrained optimizers, with decision-making taking place within a single time period. Typically, households pick schools and levels of tuition spending that maximize utility. Schools choose levels of inputs for an “education production function,” such as per pupil spending, that maximizes profits. The characteristics of the resulting equilibrium are compared across different parameterizations of the model. For a review, see (31).
32. We thank the Chicago Public Schools and the Consortium on Chicago School Research for their assistance. The model was developed in the NetLogo ABM platform (27). A working paper, including full details on the model, can be downloaded at http://ccl.northwestern.edu/papers/choice.pdf.
36. The authors acknowledge the support of the NSF and the Searle Foundation.

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Published by AAAS

Downloaded from www.sciencemag.org on October 3, 2010