Understanding What's Hard in Learning About Complex Systems

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One approach to conceptual change suggests that ontological barriers may impose beliefs that contribute to learners' misconceptions and misunderstanding of many science concepts (e.g., Chi, Slotta, and deLeeuw, 1994). If beliefs about the nature of the world affect how one explains observations and the functioning of phenomena then it is possible that the lack of certain types of explanations may impose substantial limitations to learning. Overcoming problems in learning concepts such as diffusion, force, evolution, may require instruction of an ontological category (i.e., emergent causal processes), which is unfamiliar to most novice learners. We argue that it may be possible to accomplish this objective using complex systems thinking. This study investigated the acquisition of a set of complex systems concepts through simulations in an attempt to identify which concepts are easier and which are more difficult to learn and apply as an alternative causal explanation.

Complex systems are multi-agent systems that operate under specific rules and constraints. What makes them particularly hard to understand is that there is not simply an agent controlling outcomes, rather outcomes emerge from feedback loops, probabilistic flows of information, selections mechanisms, and random changes. To assess the learner's comprehension and application of this ontologically distinct causal explanatory framework required articulating and coding their understanding into six sub-categories of emergent behaviors: Multiple Levels of Organization, Local Interactions, and Probabilistic Behavior, Nonlinearity and Random Behavior. To identify the development of understanding of these concepts, we studied a set of nine science students (equivalent to grades 12 to 13) as they explored simulations of complex systems that exhibited these behaviors.

Methods

The nine cases study students with limited or no familiarity with complex systems engaged, one at a time, in five hour-long inquiry-based instructional sessions, over a period of five weeks. Cognitive scaffolding in the form of a coach/interviewer was used to elicit talk aloud protocols. We selected three different multi-agent computer simulations designed with StarLogo™, to represent different types of complex systems (Slime, modeling tightly coupled complex system; FreeGas, modeling dissipative systems; and Wolf-Sheep, modeling the somewhat in-between system). The sessions were as follows: session 1, Slime; session 2, FreeGas; session 3, StarLogo programming tutorial; session 4, interview; session 5, Wolf-Sheep). The transcribed discussions from these sessions were coded and analyzed using the six categories described above.

Results

Not all of the six components of our complex systems taxonomy were equally daunting for the students. Posttest results confirmed that it was possible for all nine students to learn and use the concepts of Multiple Levels, Local Interactions and Probabilistic Behaviors to explain novel phenomena. Although four students were capable of adequately describing Nonlinearity and Random Behaviors, only one student acquired a sufficiently sophisticated understanding of these concepts to apply them in a far transfer task. Hence, this implies that when using complex systems thinking to facilitate conceptual change, the attribution of "causal determinacy" (i.e., interpreted as an orthogonal ontological dimension to these two above) may be the major obstacle for learners. Further study of the possible interactions between the difficulties in acquiring these target concepts (i.e., nonlinearity and random behaviors) and limitations of the selected intervention are required.

References

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