Assessing the Complexity in Complex Causal Learning in Terms of Perception, Attention, and Reasoning

Tina A. Grotzer[1] M. Shane Tutwiler[1] S. Lynneth Solis[1] Katarzyna Derbiszewska[1] Megan Powell[1] and Caroline Courter[2]
Harvard Graduate School of Education[1], University of North Carolina, Wilmington[2]

Introduction to the Problem Space

The Next Generation Science Standards call for integrating the Cross-cutting Patterns of Causality and Systems Thinking into science learning and for building understanding of these structural concepts. How do we know that students are gaining these understandings? There are many puzzles and trade-offs in the assessment process to be navigated as we attempt to assess these complex understandings. Here we explore two of the many challenges that have arisen in our work: 1) How to assess reasoning that is extensive in its nature given human cognitive tendencies towards efficiency; and 2) How can we go beyond assessing merely the ability to reason about complexity to also consider learners' perception of and attention towards instances that call for complex causal reasoning? The work reported here draws upon questions that have arisen in the context of other studies that we were conducting.

Study 1: How can we figure out what students know given the extensive nature of complex causal phenomena and the human cognitive tendency towards efficiency?

Close-ended assessments heavily cue students as to what is being assessed. The ability to know whether students would perceive instances in which certain kinds of reasoning are relevant is lost. Open-ended assessments enable us to see how students structure their causal explanations. However, they can fall prey to factors of efficiency. Students try to figure out what is being asked and respond until they think the answer is enough. This is especially at issue for complex causal and systems thinking because the nature of the phenomena is extended and may involve multiple candidate causes or effects. It becomes challenging to separate students' ability to reason from how far they extend the narrative of their explanation. In this study, we wanted to assess whether students included possible distant causes in their explanation of effects witnessed locally through open-ended interview questions. It was a Design-Based Study and early findings revealed mostly local responses. So we developed and administered to fourth and sixth graders a multiple choice instrument that gave local and distal choices in an attempt to lend insight into whether students couldn't generate more extended responses, weren't inclined to, or actually preferred local explanation.

Study Design

- In-depth study across the school year with interviews at multiple points
- Urban public schools in the Boston area
- 2nd, 4th, & 6th graders
- Diverse SES/Ethnicity
- Design-based research
- Clinical interviews, open-ended scenarios (n = 10)
- Multiple-choice instrument (4th & 6th graders, n = 23) all scientifically accepted answers, 2 posed locally; 2 distally; with obvious or non-obvious mechanisms.
- Emic coding, looking for emergent patterns
- Etic coding, frequency of local vs. distant responses
- .84 Cohen's Kappa)

Sample Question

1. Scientists were hired to study the trees in Canada. They have discovered that trees all over the country are less healthy now than they were 20 years ago. Here are some reasons why the trees might be less healthy. Circle the answer that you think is best.

a. Rain is falling onto the leaves and chemicals in the rain are hurting the trees. The leaves turn brown, shrivel, and eventually fall off.

b. Automobiles and factories all over put chemicals into the air. These chemicals fall on the trees when it rains, damaging the trees.

c. Insects harm the trees by climbing on them and eating different important parts, including their leaves, their roots, and their trunks.

d. There has been an increase of insects in some parts of the country and they are moving to find new trees. These insects are hurting the trees.

Why do you think that is the best answer?

If you could choose a second best answer, which would you choose? Write the letter of your second choice here. _____

Why would you choose it?

While students generated mostly local explanations in response to open-ended interview questions (See Figure 1), they chose distal responses as often as local ones on the multiple choice (See Figure 2). It makes it challenging to separate students' ability to reason in particular ways from how far they extend the narrative of their explanation. It confounds what they know with a tendency to prune explanations to their most efficient (and not necessarily complex) forms in communicating understanding. Here they were less likely to generate distal explanations, but is this due to ability or modes of responding to questions about phenomena with extended possible responses?

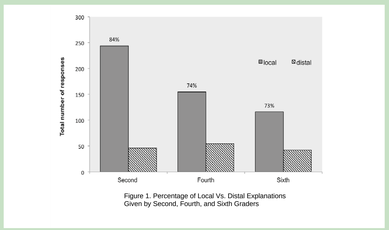


Figure 1. Percentage of Local Vs. Distal Explanations Given by Second, Fourth, and Sixth Graders

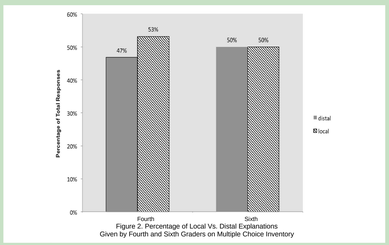


Figure 2. Percentage of Local Vs. Distal Explanations Given by Fourth and Sixth Graders on Multiple Choice Inventory

From: Solis, S.L., Derbiszewska, K.M., & Grotzer, T.A. (2014, March). An in-Depth Study of Students' Default Explanations of Action at an Attentional Distance. National Association for Research in Science Teaching (NARST), Pittsburgh, PA., March 31, 2014.

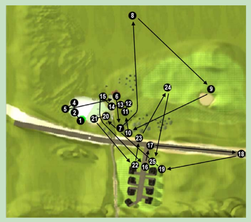
Study 2: How can we assess the perception and attention to opportunities to reason about complexity in addition to the ability to do so?

In real world problem-solving, students need to perceive the relevance of particular forms of reasoning, know how to apply them, and be inclined to do so—what Perkins, Tishman, and Jay (1995) refer to as "Sensitivity, Ability, and Inclination." Perception of occasion or "Sensitivity" is often the greatest challenge. Even when students reveal the ability and inclination to reason in particular ways, they often fall short on recognizing opportunities (Perkins et al, 2000). Formal assessments of complex causal reasoning draw students' attention to the relationships resulting in cuing that removes perception and attention from the equation. It takes away the primary challenge of what students notice and decide to reason about (known as "the ontological challenge" in the causal induction research.)

Therefore, in a case study of students' reasoning about the complexity in ecosystems, in addition to formal assessments, we sought ways to see how their perception of what to attend to changed over time. Pairs of students were investigating an ecological problem that they discovered in a virtual world called EcoMUVE. We video-taped their movements in the virtual world, transcribed their conversations, and used the back-end log-file data. This corroborating data allowed us to consider their behaviors and how they attended to certain variables as they gained information about the ecosystem and used affordances built into the world to help them explore it. The mappings combined with each team's tool use and transcripts of their conversations offer rich information about what variables they viewed as important to the ecological issue and what affordances in the virtual world helped them to realize the importance.

Study Design

- Two classes (combined 5th/6th gr.)
- ~20 students in each class (n = 39)
- Middle/Upper class SES /ethnic diversity
- Both taught by the same science teacher
- Students explored EcoMUVE for two weeks (approximately 8 class sessions)
- School is adjacent the pond that EcoMUVE was modeled upon and students have taken three or more trips a year since Kindergarten.
- Two independent coders developed mappings of the students' movements to check for reliability.


Session 1- Initial exploration


Session 3- A fish die-off is discovered!


Session 5- Investigating a pipe connecting the pond to more distal areas.

Spatial Domains within EcoMUVE

Chloe and Sean– Movement Patterns

Mappings from: Courter, C.J., Grotzer, T.A., Derbiszewska, K.M., Powell, M., Tutwiler, M.S., Kamarainen, A., Metcalf, S.J., & Dede, C. (2014, March) A case study contrasting students' exploration behaviors of a complex causal scenario in a virtual world: Mapping proximity and goal directed movement in EcoMUVE. National Association of Research in Science Teaching (NARST) Conference, Pittsburgh, PA., March 31, 2014.

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