Thinking Within and Between Levels:
Exploring Reasoning with Multi-Level Linked Models

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Abstract: This poster presents a pilot study with a prototype technology that allows learners to link agent-based models written in NetLogo models and run them simultaneously as a coupled system. We describe ongoing design work using this prototype to investigate how learners conceptualize multi-level modeling of complex systems in ecology.

Keywords: agent-based modeling, NetLogo, complex systems thinking, ecological complexity

Introduction

Agent-based models (ABMs) have been used for decades as educational tools, helping students conduct the analytical inquiry of modeling and reason about complex systems (Wilensky, 2001). Learners investigate the behavior of a complex system by "growing it" from the simpler behaviors of its constituent *agents* (Epstein & Axtell, 1996). This process involves identifying agents (e.g., wolves, sheep, and grass), and defining computational rules for their interactions (e.g., "wolf-hunts-sheep" or "sheep-seeks-grass"). An ABM may include thousands of computational agents, whose combined activity can give rise to emergent system-level behavior (e.g., the stability and fluctuation of a wolf-sheep-grass ecosystem). Importantly, the process of modeling involves delimiting and simplifying reality: creating representations whose *utility for a purpose* compensates for their loss of verisimilitude (Box, 1976). However, once an ABM has been built, learners often have ideas and questions about how the phenomena it highlights may interact with features or systems in the world "outside" of it. We see this drive to explore connections of an ABM as a powerful gateway to new kinds of model-based inquiry and as an important synthesizing counterpoint to the analytical work involved in creating a single model. Placing a model in an *ecosystem of related models* could offer a powerful bootstrap to reasoning about multi-tiered and nested complex systems. Here we describe a design study addressing the question, How do learners reason across *and between* models when programming connections between them?

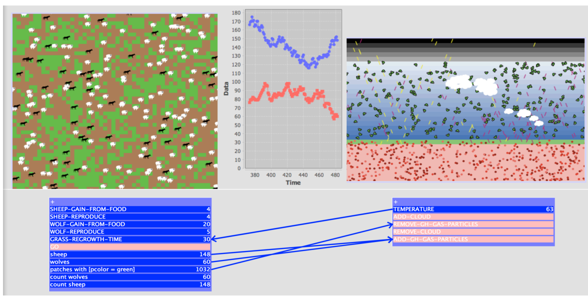

Figure 1. The ModelConnector GUI. Arrows indicate learner-created relationships between models.

Methods

To explore learners' ways of thinking about linked models, we built a prototype environment (ModelConnector, see Figure 1), which executes a pair of NetLogo (Wilensky, 1999) ABMs simultaneously (here, the wolf-sheep-grass ecosystem and a Climate Change model of greenhouse effects). Through a point-and-click interface, learners construct new computational relationships between the two models, which are enacted during the execution of the model-pair. ModelConstructor provided us an environment to investigate learners' reasoning about these models and their conceptions of links between them. Because little research has been done on learners' conceptions of Multi-Level Linked models, we took a broad, open-ended approach in our study. We recruited two high school science teachers, Tom and Taylor (pseudonyms) who had previously used ABMs in their classrooms. We had them collaborate using ModelConnector to explore and discuss relationships between Wolf Sheep Predation and Climate Change, as follows. First, they worked with each of the models individually, spending 20 minutes on Wolf Sheep Predation and 10 minutes on Climate Change. In this phase, they identified and explored the rules and behavior of each. When we felt they had sufficiently understood the individual models, we opened ModelConnector for them to investigate links between them. They engaged in this work for 25 additional minutes, discussing and programing links that caused the two models to affect each other. During this entire process, we conducted an unstructured interview about how the two systems might be related. The session was video recorded, and the participants' software interactions were captured with Camtasia.

Analysis

We first did content logging of the resulting video, identifying episodes in Tom's and Taylor's reasoning about the models and reducing our video data from around 68 minutes to around 9 minutes. These episodes were selected on the basis of whether either participant talked about *what* in the two models might be connected, *how* they might be connected, or *why* they might be connected. We then coded the selected video in greater detail, taking an open-ended approach informed by prior research on using ABMs for studying complex systems reasoning. In this poster we present two particularly interesting codes from this process: "within-model questioning", and "unpacking relationships". We provide an example of each, below.

Findings

When asked how the models might affect each other, Tom immediately suggested that climate change would affect vegetation, while Taylor believed the most important relationship was how the ratio of wolves and sheep to the amount of grass would contribute to greenhouse gases. When asked to elaborate on the former, they said,

> Taylor: So if you say that it's less water because it's hotter out, then [grass growth] would go down. But with some plants [...] they can grow even faster because they have more light and more energy
>
> Tom: And it may affect plants at different levels of temperature change. Again, initially it may be promoting more growth, but once you reach a certain point, it may have a detrimental effect.

Thus, when asked to reason about the relationships *between* the two models, basic assumptions *within* the models became salient to the participants. When they had earlier discussed the Wolf Sheep Predation model, they did not mention or critique the model's assumption that all grass grows equally. This suggests a potentially powerful use of inter-model reasoning: creating these links may enable learners to develop new perspectives about the individual models. We then asked the participants to examine Taylor's idea that the 'ratio between wolves and sheep to grass' would impact greenhouse gasses as specific relationships. She and Tom began unpacking that idea into the individual relationships it comprised: (1) wolves and (2) sheep individually *increase* greenhouse gasses through flatulence; and (3) grass *reduces* greenhouse gasses through photosynthesis. In this way, Taylor and Tom moved from thinking about the relationship at the aggregate level (ratios between populations) to a more agent-level kind of reasoning in which each individual affects the system. This kind of reasoning has been shown to be particularly productive for reasoning about complex systems. This suggests that linking models may help learners to concretize their intuitions so they can be expressed in specific behaviors. It helps them unpack relationships and reason about agent-level mechanisms.

Conclusions and implications

While very preliminary, our data suggest that inter-model reasoning is a fruitful subject for further study: Our participants were able to reason productively about the relationships between models, and this further helped them critically assess each of the models individually. Our future research goals include designing and testing curricular units that draw on these cognitive affordances of Multi-Level Linked modeling, and on increasing the power and expressivity of software environments that support learners in creating Multi-Level Linked models.

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