Representing Modeling Relationships in Systems: Student Use of Arrows

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Abstract: Developing and constructing models is considered a core scientific practice by the Next Generation Science Standards (NGSS). Complex systems present a challenge for students to model due to their dynamic, unintuitive, and interconnected elements. This study aims to examine how 5th-6th grade students symbolically represent connections between elements of complex systems models. It looks specifically at the usage of arrows as a semiotic tool that students use to model various relationships in a system.

Keywords: modeling, science learning, complex systems, collaboration

Introduction

Modeling complex systems can be particularly challenging for students because they have many dynamic and interconnected elements that may not be salient for novice learners (Hmelo-Silver et al., 2017; Wilensky & Resnick, 1999). Asking students to represent their conceptual understanding through creating and iteratively refining models can help them develop an understanding of both the underlying concepts, and the kinds of modeling practices that are core to the scientific enterprise (Schwarz & White, 2005). Prior research has demonstrated that the *Phenomenon-Mechanism-Components* (PMC) conceptual framework can help students to attend to key dimensions of a complex system as they model it (Hmelo-Silver et al., 2017). Models that align to a PMC framework explicitly represent the components in a system, the mechanisms that connect them, and the overall phenomena produced through their interactions. As part of a larger study funded by the National Science Foundation (#071750-00001A/B) exploring how students use evidence to create and build models of complex systems, we explicitly incorporated the PMC framework as a scaffold of students' modeling activities to support systems thinking. Students were instructed to create box-and-arrow models (see Figure 1) of an aquatic ecosystem with boxes intended to represent components, and arrows intended to represent the mechanisms relating components. However, students' use of arrows were quite varied, revealing a range of ways that they think about and represent the relationships between the different aspects of the system. In this poster we answer the question: how did students use arrows to depict relationships in a model of a system, and what might this reveal about their understanding of systems and modeling?

Methods/Analysis

Over the span of two days, 6 groups of 4th-6th grade students were tasked with creating box-and-arrow models of aquatic ecosystems. We guided students in drawing an example relationship between two components (that fish eat food) and prompted students to build models based on findings from numerous pieces of empirical evidence and virtual simulations depicting conditions of fish living in a tank that students were free to explore.

As a group, we deductively developed a prototype of a multi-dimensional coding scheme. First, arrows were examined in isolation of the rest of the model as representing either what students identified to be components, descriptives/labels, or interactions. Second, each interaction was then coded and mapped (see Figure 1) based on the number of relationships being represented and the average level of these relationships' explicitness of directionality using the following criteria. "Level I" relationships contain direction-neutral language (i.e. impacts, affects, lives in) while any directionality is implied via arrow; both 'Level II' and 'III' relationships use language to convey direction, although 'Level II' relationships employ direction-implicit or simplified language (i.e. eats, cleans, turns into) and 'Level III' relationships employ direction-explicit language to convey a specific correlation between components.

This categorization builds off Sinha's (2013) mechanistic reasoning coding scheme which was developed to expand upon how the PMC framework supports student reasoning about the use of mechanisms within models.

In this scheme, mechanisms were identified as falling into one of four “Levels” ranging from superficial causal mechanisms (i.e. “dirty water kills fish) to complex, multilinked sequences of causal mechanisms (in which a longer explanation contextualizing the mechanism in the system is needed).

Findings

In applying our coding scheme to the six student models, we found that student use of arrows in their models of aquatic tank systems varied both between groups and within models. This poster will include applications of the coding scheme to models that exemplify the diversity of how students are conceptualizing arrows. A sample application of the scheme applied to a student model can be seen in figure 1. It appears that using arrows to represent mechanisms between different model components was not entirely intuitive, with students using arrows to represent a wide range of relationships including interactions and outcomes, often encompassing multiple of these dimensions.

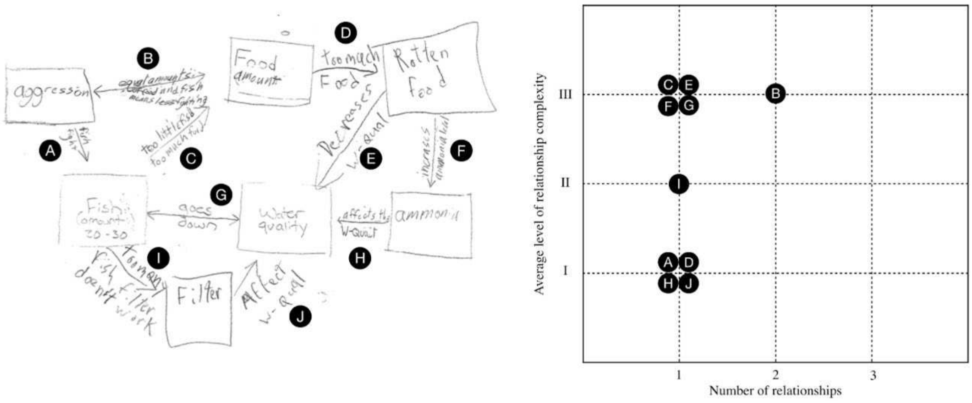

Figure 1. Sample student model (left) and a map of the relationships depicted by arrows (right).

Conclusions/Implications

In looking at students’ use of arrows in modeling complex systems, we demonstrate that students’ expectations and practices involving their use of arrows are inconsistent, resulting in variant models and thus diverse understandings of the underlying system. Mapping the student arrows using our coding scheme provides insights into how students understand each of the relationships within their emerging model. These insights contribute to how we understand relationships within the scope of systems thinking informed by the present PMC framework (Hmelo-Silver et al., 2017). Our goal in future work is to use this understanding to scaffold students’ iterative revision of their models, helping to promote a richer sense of both the underlying system, and the representational features that can make the system dynamics visible. We expect that students who have a rich sense of the interconnections within the system will be more inclined to represent them with arrows that capture directionality and mechanism. At the same time, we hypothesize that students who expect arrows to convey these features are also more likely to revisit the available resources to identify those nuances to capture them within their representation.

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