Impact of blended immersive virtual world and programming curriculum on student perspectives about scientific modeling

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EcoMOD uses a design-based research approach to develop and study an elementary curriculum that combines an immersive virtual environment with interactive computer programming interface to support computational modeling, ecosystem science understanding, and causal reasoning. Here we report on changes in students' perspectives on modeling before and after use of the fifteen day interactive, technology-based curriculum in a 3rd and 4th grade classroom. Pre-post interviews were conducted with ten students, and preliminary results suggest that students demonstrated an increased awareness that models are designed for a purpose, and the purposes students described aligned more closely with scientifically relevant activities like prediction, investigation and explanation. Students also increased in their level of sophistication related to ecosystem science understanding and causal reasoning.

Objectives

Integrating modeling into the elementary science curriculum offers the potential to meet important 21st century learning goals, including understanding causal relationships in complex systems and infusing computational thinking into disciplinary contexts. These learning objectives have received attention in middle school and high school curricula (Ryu, Han, & Paik, 2015; Vattam et al., 2011), but few examples exist in elementary grades science instruction (Schwarz et al., 2007). Research has revealed that even young students can demonstrate sophisticated reasoning and understandings related to complex causal patterns and features (Gopnik et al., 2004; Grotzer & Basca, 2003; Grotzer & Solis, 2015), and can engage in computer programming activities (Gregg et al., 2012). We hypothesize that through integrating interactive modeling tools with immersive virtual environments we might better support ecosystem science understanding, complex causal reasoning and computational thinking for third grade students.

Theoretical Framework

Prior research on immersive virtual environments indicates they can support motivation towards science and engagement in authentic scientific practices. Modeling is a core practice of modern science by which scientists link conceptual ideas to mathematical and computational representations of a system. Modeling is particularly prevalent in ecosystem science, where scientists seek to understand complex problems at the intersection of natural and social systems (Hogan & Weathers, 1999). The prevalence of modeling as a tool for understanding complex systems lends a strong argument for using ecosystem science as a focal point for studying the design of model-based instructional materials that are situated authentically within the domain of inquiry (Manz, 2012).

Much of the work that has been done to date on the use of models in science instruction has focused on physical and symbolic models (Nelson & Davis, 2012); there are fewer examples of curricula that explicitly engage students with the computer code behind computational models. When programming is introduced to students, it is often done as separate from a disciplinary context (e.g., through "Hour of Code"). While recent attention has been paid to incorporating modeling practices and computational thinking across the K-12 curriculum (Schwarz et al. 2009;

Lee et al. 2014), important questions remain about how young learners think about models in the context of domain-rich problem spaces.

Design of immersive learning environment for modeling

In the 15-day, 3rd-4th grade EcoMOD curriculum, students explore both a realistic immersive 3D ecosystem and a visual block-based programming environment to develop understanding of ecosystem science and computational modeling.

The scenario represents the complex causal relationships within a virtual forest, in which over time, a beaver builds a dam, forming a pond, and later, woodpeckers arrive, excavating tree cavities which then become homes to other species. Students explore the virtual world, collect data, travel in time and make observations. They use a point of view (POV) tool to role-play a beaver, and later a woodpecker, this virtual enactment helps them notice and reason through species' specific behaviors.

During the curriculum, students engage in programming in order to construct agent-based models, first of a beaver, then a woodpecker, programming the rules for the behaviors of the organisms. Using the visual block-based programming tool, students test and debug their computational model, and observe the agent's interactions with a 2D model of the ecosystem, in which they see the emergent impacts of their agent's behaviors. Moving back and forth between immersive and computational activities, students develop and refine their theories about why changes occur in the ecosystem over time.

Methods & Data Sources

A pilot study of EcoMOD was conducted during May-June 2018. The study included two test sites: a suburban 3rd grade class with one teacher and 21 students, and an urban 4th grade class with two teachers and 22 students. Each site used EcoMOD for 15 50-minute class periods, three times per week. This paper focuses on pre-post interviews conducted with ten students, five from each class of which five were girls and five were boys.

The coding scheme applied to the data set is based on prior work on student perspectives on scientific models. Here we provide a brief summary of the literature that informed development of the etic coding scheme used in this analysis:

It is a struggle for learners to move from thinking of models as "copies" of (or that they "look like") the real phenomenon to a generative conception of models that should "work like" the real phenomenon. (Schwarz et al. 2009; Lehrer and Schauble 2010; Pluta, Chinn & Duncan 2011). Students across a broad age range hold a view of models as direct copies of nature (Grosslight et al. 1991; Treagust et al. 2002). If students think that a model must directly represent the surface features of the phenomenon, this will limit the epistemic criteria they might apply for evaluating models (Pluta, Chinn & Duncan 2011).

Recent work emphasizes the importance of understanding that models are designed by scientists for a purpose (Schwarz et al. 2009; Pluta et al. 2011). Both Schwarz and others (2009) and Pluta and others (2011) emphasize the important role of specifying the relationship between a model's purpose and it's design/form/structure in order to make explicit the often tacit epistemological role that models play in inquiry. Prior work shows that in the absence of instruction, students tend to have low levels of awareness that models are created for a specific purpose (Grosslight et al. 1991).

We developed the following primary research question to assess student perspectives on modeling:

1. How do students characterize the utility or purpose of models in science?
    1. What proportion of students conform to a "looks like" vs. "works like" orientation towards models on the pre and post interviews?
    2. Do students talk of models as designed for a purpose? What purposes do they suggest?

In addition to these primary questions related to perspectives on modeling, student responses also indirectly provided evidence of their perspectives in two other domains relevant to our project goals. So we also include analysis of the following secondary dimensions of the data set:

- What degree of sophistication in understanding ecosystem science concepts (e.g., habitat, organism interactions, how ecosystems change over time) do students demonstrate?
- To what degree do students incorporate causal language and concepts in their responses?

Semi-structured pre-post interviews, which included four main conceptual areas with 3-7 sub-questions (examples provided below), were conducted with individuals during a ~40 minute period. The prompts were designed to assess student perspectives on modeling. Students were given opportunities to interact with three representations of a natural landscape during the interviews a) a photograph of a forest on paper, b) an immersive, interactive 3D virtual model of a forest environment on a laptop computer (Figure 1a), c) a 2D NetLogo interactive model of an environment depicting wolf, sheep and grass on a laptop computer (Figure 1b).

1. Thinking about the system (in relation to the photograph): "What questions do you have about this place?"; "What might you do to investigate this place?"
2. Models as representations of the real world (in relation to... immersive 3D model (first); ...2D NetLogo model (second)): "What is the same/different between this model and the actual environment?"; "How does recreating the ecosystem like this help the scientist understand this ecosystem better?"
3. Comparing two models (comparison of 3D and 2D model): "Why might a scientist use one model over the other?"; "What is not shown "accurately"? What is left out?"
4. Modifying models: "If you could change something in this model, what would you change? Why?", "How would you change it?"

Data Analysis:

All interviews were fully transcribed, and analyzed (n=8). We began with structural coding, based on three main themes (perspective on modeling, ecosystem science understanding, and causal reasoning) (Namey et al. 2007). Following structural coding, we used an etic approach to code the dataset using themes outlined in the literature (see Methods). Using a process of peer debriefing (Lincoln & Guba, 1985), the final coding scheme was refined through discussion between two researchers, and then applied to the preliminary data set by one researcher. The second researcher independently reviewed application of these codes, and any mismatches were discussed and resolved. Given that this data set is derived from a pilot study that is part of a larger design-based research project, we do not aim to make claims about the generalizability of these findings beyond the scope of the small population that took part in our study. The generalizability of our findings to other populations would require further study.

Results

Students used language to describe aspects of how models "look like" as well as "work like" real ecosystems on both the pre and post interviews.

Interviewer (immersive 3D, pre): What makes it a good model of a forest?

Natalie (pre): Well, it has the animals and what will be in a forest. Like what we will expect in a forest and what you will see and what is going to be there and what you might encounter [LOOKS LIKE]... *and if you will hurt an animal, you might get attacked in real life. That could happen.* [WORKS LIKE]

Interviewer (comparing 3D & 2D): So what's the same between the two models, and what's different?
Natalie (post): There's both animals and there's both grass. [LOOKS LIKE] *And... Like their populations both go up and down… And it's kind of like they do the same thing because the wolves eat the deer.* [WORKS LIKE]

The "works like" codes were observed more frequently in relation to the 2D NetLogo model (n = 35 references out of 60) as opposed to the more visually rich immersive 3D model (n = 24 references out of 60). On the post-interviews references to "works like" were more commonly aligned with ecologically relevant processes or interactions.

Three students recognized models as designed for a purpose on the pre interview, while five mentioned this aspect in the post-interview. For example during the pre-interview Faith said that models were designed for a purpose, and suggested that the purpose was related to learning about plants or animals. On the post interview, she speaks about models as being designed for a reason, and that what is included depends on what is being investigated. On the post-interview more students included descriptions of how models might be used to predict or explain, for example:

Interviewer (in response to mention of prediction): I'm wondering, can models help us see how a place might be in the future? How do you think they can do that?
Faith (post): For example, like here. It's like 2020. It's because... Like it's kind of a prediction for what has happened between the past years and then what may happen if it continues doing it.

In our descriptive analysis of our secondary dimensions, we note that students used more sophisticated ecosystem science vocabulary and described a greater number of investigative strategies on the post-interview (n = 10 instances and 8 instances, respectively) compared to pre (n = 7 instances and 4 instances, respectively). On the pre-interviews students often referred to plants and animals, while on the post-interviews they refer to specific ecosystem science concepts like habitat, animal behaviors, and how ecosystems change over time. Also, students use of causal language and concepts were similar in number on both pre and post, but the causal language was more nuanced in the post-interview compared to pre.

Significance
This analysis offers insights for researchers and practitioners who aim to better understand how technology can be integrated into everyday classroom activities, and leveraged to support learning of scientific and computational practices, like computational modeling, in the elementary classroom. Given current interest in computational thinking across the field (Sengupta et al. 2013), as well as a relative lack of learning experiences that engage young students in discipline-specific programming activities, we anticipate this work to be of interest to a broad audience.

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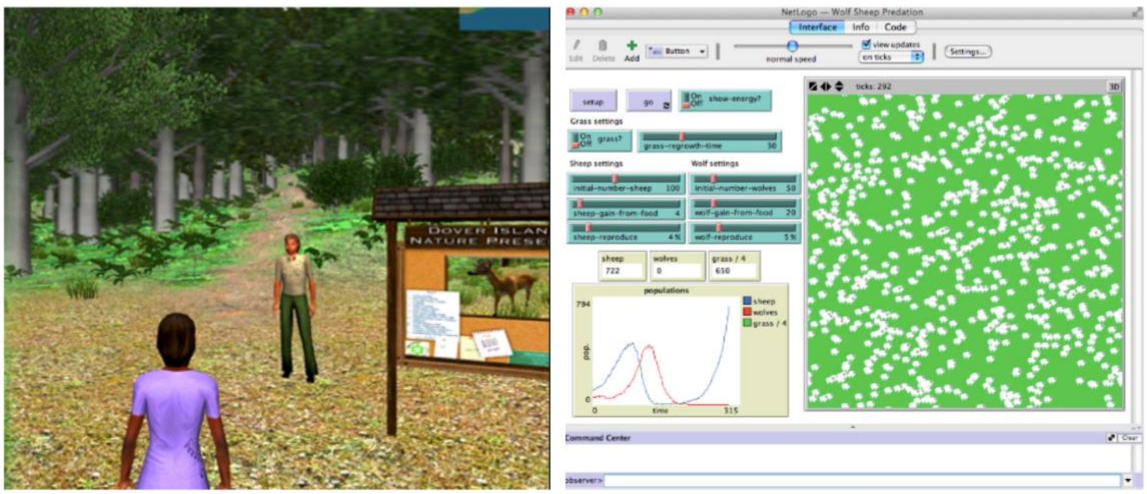

Figure 1. Screenshots of the 3D immersive model of a forest (a) and 2D NetLogo model depicting wolves, sheep and grass (b) that students explored as part of the pre-post interviews.