Secondary Students' Model-Based Reasoning about Earth Systems: Practice, Epistemology, and Conceptual Understanding

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Abstract: To become scientifically-literate, students must develop competence with the use of computer-based models to reason about Earth systems. In this poster presentation, we share early-stage work spanning multiple projects using technology-enabled modeling tools grounded in 'big data' with students in secondary science learning environments. The poster will showcase the modeling tools and design-based research approaches, as well as provide a context for discussion about theoretical, empirical, and design aspects of the projects.

Introduction

Today's most pressing global challenges span Earth systems at local, regional, and global scales. The problem-solvers and innovators who will be faced with addressing these challenges must develop scientific literacy. Models are a critical tool with which scientists study and seek to solve these challenges. Scientists use computer-based modeling tools grounded in 'big data' to both explain and predict systems-level phenomena. While technology-enabled tools have been a core focus for learning scientists for many years, there remains a great deal to learn about how to make these modeling tools available to students in meaningful ways and support their productive by students to reason about Earth systems. We are engaged in early-stage design-based research across multiple grant-funded projects to implement computer-based modeling tools in secondary (high school) classrooms. This work is grounded in a theoretically- and empirically-grounded learning performances framework for model-based reasoning about Earth systems. The purpose of this poster presentation is to a) share preliminary findings from project research and b) interrogate and revisit this framework as both a theoretical and analytical tool for understanding and studying secondary students' model-based reasoning.

Computer-based modeling tools

Our current work involves two computer-based modeling tools: The Hydrogeology Challenge (HGC) and Easy Global Climate Model (EzGCM). Both provide technology-enabled interfaces that allow students to 'shortcut' the complex computations that commonly underlie numerical models. The HGC (Fig. 1) is an online, computer-based learning tool used to explore hydrologic concepts associated with subsurface water. Developed by a U.S.-based non-profit organization, the HGC makes national geologic and hydrologic datasets accessible to students. Within the HGC interface, students conduct simulation-based experiments to investigate how groundwater flows, factors affecting flow rates, including gradient, porosity, and substrate. These experiments are embedded within both real and hypothetical real-world scenarios involving water issues.

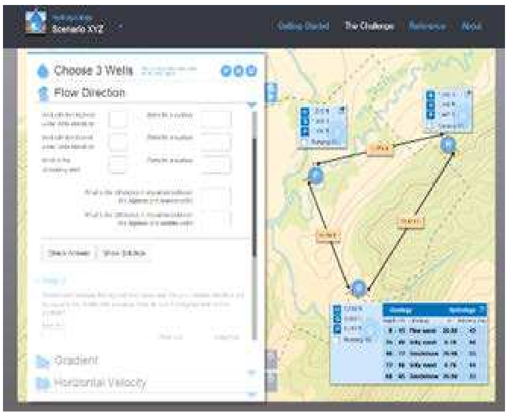

Figure 1: Hydrogeology Challenge Screenshot.

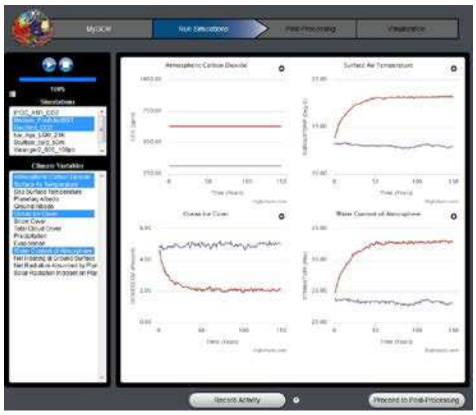

Figure 2: EZ Global Climate Model Screenshot.

EzGCM (Fig. 2), developed at Columbia University in cooperation with the NASA Goddard Institute for Space Studies, is a web-based global climate modeling suite designed to provide non-scientists with authentic climate modeling experiences. Drawing from NASA's GCM development program and using actual data from U.S. global climate modeling efforts, EzGCM streamlines and makes transparent the key features of climate models that help scientists simulate and analyze Earth's climate system. Through EzGCM, students are able to participate in the science of climate modeling, including running simulations, post-processing model output, analyzing model results by creating scientific visualizations, and communicating results, all crucial epistemic practices through which students engage in model-based reasoning about Earth's climate.

A learning performance framework for scientific modeling

Competency with scientific modeling requires students develop abilities to use models in ways that mirror the practices of science to reason about natural phenomena. Modeling competence is developed through interactions between the learner, the model, and the real-world phenomenon. We draw upon Harré's (1970) concept of 'projective convention', situated and activity-based perspectives on learning and expertise (e.g., Engeström, 2008), and scientific modeling in educational contexts (e.g., Schwarz et al., 2009) to foreground the practice-based and integrated nature of scientific modeling. Competence is defined by 'knowledge of' scientific models and modeling, as well as how users apply models to make sense of natural phenomena. These assumptions are captured in student *learning performances* (Krajcik, McNeill, & Reiser, 2007), which define practice-based evidence of learning. The learning performances framework we articulate for scientific modeling is comprised of three dimensions: modeling practices, epistemic dimensions of modeling, and disciplinary concepts.

Research methods

Both projects involve design-based research (Collins, Joseph, & Bielaczyc, 2004) to engage in iterative development of curriculum, refinement of the modeling tools, creation of research measures that embody theoretical constructs, and data collection and analysis. Curriculum development involves a process of construct-centered design (Shin et al., 2010), through which the modeling tools are being piloted in eight secondary science classrooms in the United States. We are collecting a diverse set of data in these classrooms, including student assessments and artifacts, clinical interviews, observational data, and implementation logs.

Preliminary findings and points of discussion

Preliminary analyses of project data point to key aspects that will lead to productive discussions with conference participants. First, even though the learning tasks in the curriculum modules are designed to target all theoretical learning performances, evidence for some performances is far more robust than others. Is this reflective of students' model-based reasoning within these domains, or perhaps reflective of limitations in learning environments design and/or measurement of anticipated student outcomes? Second, what are core epistemic elements of scientific modeling, and perhaps scientific practice more generally? While the learning performances framework embodies contemporary perspectives on epistemological dimensions of modeling in science, not all have proven to be equally useful and/or applicable as educational design heuristics or research constructs. What are key aspects of models and modeling that make them scientific? What levels of conceptual understanding do students exhibit and what levels should they be expected to attain? How do they manifest themselves in certain modeling practices in which students engage to investigate natural phenomena? Conversations about the nature of epistemology as it applies to Earth systems modeling using technology-enabled tools will help clarify epistemic dimensions of students' model-based reasoning about Earth systems.

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