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“More Than Just Making Stuff Explode”: The Impact of Engagement With Scientific Practice Beyond Disciplinary Content

Engin Bumbacher, University of Teacher Education Vaud, Switzerland, engin.bumbacher@hepl.ch
Leah Rosenbaum, Teachers College, Columbia University, leah@tltlab.org
Paulo Blikstein, Teachers College, Columbia University, paulob@tc.columbia.edu

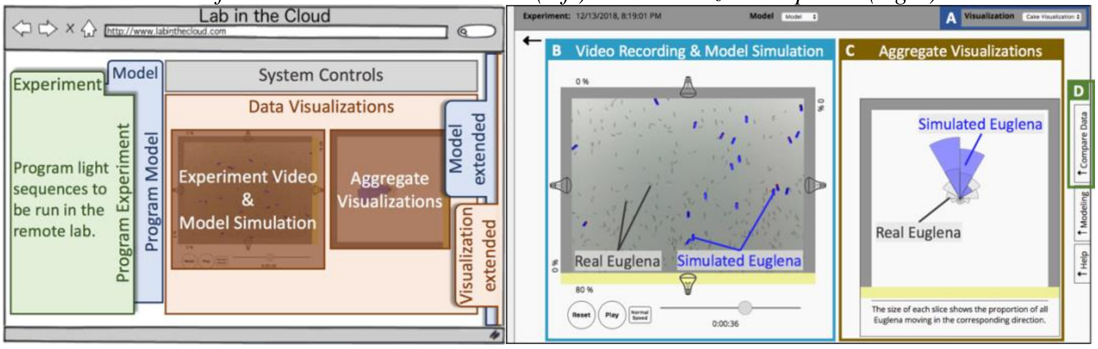
Abstract: As part of a larger project, this study evaluates middle school students’ learning from a technology-based, evidentiary reasoning unit. Post-unit survey responses indicate students developed a deeper understanding of the nature of scientific work and of productive scientific mindsets. These take-aways beyond content knowledge emphasize the learning opportunities and outcomes that can arise from engaging learners in authentic scientific practices.

Introduction and background

Recent science education reforms work to shift science learning beyond a mere understanding of scientific content to include knowledge about the function and interplay of the different scientific activities, often referred to as understanding of the nature of science (NOS) (Williams & Rudge, 2016). Research suggests that students’ understanding of NOS be developed alongside their science content and procedural knowledge through practice-based teaching approaches (Duschl & Grandy, 2013). The design of practice-based learning activities that foster content, procedural, and NOS learning remains a persistent challenge (Williams & Rudge, 2016).

Acknowledging the intricate relationship between the design of practice-based science activities, how students engage in scientific practices, and what they learn about science through the activity, this poster addresses the following research question: what do students take away about the nature of science and how scientists work from engaging in a practice-based, technology-driven learning activity? We report on a middle school unit in which students coordinated real data with computational models to reason about the behavior of *Euglena gracilis*. Throughout, students had to make decisions about what kind of data features and patterns to use to evaluate their hypotheses and models. We propose that above-content take-aways emphasize the broader- than-expected learning opportunities and outcomes of engaging learners in authentic scientific practices.

Figure 1
Lab in the Cloud software environment overview (left) and visualization options (right)



The size of each slice shows the proportion of all Euglena moving in the corresponding direction.

Methods

Based on the Bifocal Modeling framework (Blikstein, 2014), which juxtaposes scientific models and real-world data for real-time comparison, we designed Lab in the Cloud (LiC), a web application that integrates a remote laboratory (Hossain et al., 2016) with a modeling and data visualization environment. In the Experiment area (Figure 1, green), students remotely controlled the lab’s lighting to vary conditions for live *E. gracilis*. They also programmed models (Figure 1, blue) to enact their theories of *E. gracilis* phototaxis. Students studied the resulting experimental and model data in the same visualizations (Figure 1, orange), both as an overlay (Figure 1, part B) and in aggregate (Figure 1, part C) (Bumbacher, 2019), to modify and refine their theories about *E. gracilis* phototaxis. The 76 participants (39 F, 37 M) were 7th grade students in a Northern California public school and all had the same life science teacher.We analyzed students’ answers to the nature of science question “Did you learn anything about science and how scientists work that you did not know before? If so, what did you learn?” through their post-unit survey responses. Through multiple rounds of independent and collaborative thematic analysis (Braun & Clarke, 2006), we refined the codebook presented in Table 1 and achieved Cohen's Kappa of at least 0.80 on 25% of the corpus. The remaining responses were coded independently.

Table 1
Codebook for students' reported learning from the E. gracilis phototaxis unit.

Learning Area	Example(s)	Students	# Ideas	
			Mean	**St. Dev.**
Nature of Scientific Work		**75%**	**1.2**	**0.4**
Experiments & Data Collection	"scientists learn new things and experiment with technology like using computers or microscopes."	29%		
Models & Tools	"I didn't know scientists used robots to mimic the animal or plant."	45%		
Interpretation & Argumentation	"If you don't have good evidence to support your claim, no one will believe what you are saying."	14%		
Scientific Mindset		**42%**	**1.3**	**0.5**
Patience & Perseverance	"you don't always figure things out the first time and that scientists need to be patient when they experiment."	12%		
Attention to detail	"scientists carefully observe different actions or outputs with precision and close observation."	28%		
Other:	"...scientists... could get proven wrong. But that is not a bad thing."	14%		

Findings

Almost all students (91%) reported learning science content (Table 1). Encouragingly, 75% of students reported learning about sophisticated aspects of NOS (or in a students' words, "they study more than just experiments and making stuff explode.") and over 40% reported learning about scientific mindsets. Neither of these areas were overtly discussed by the instructional unit and, thus, represent above-content learning. Students tended to report NOS learning about novel tools - software, computer modeling, and robotics - that go beyond mere experimentation and data collection. "Attention to detail" was the most common idea within reported learning about scientific mindset. Students' reported NOS and mindset learning can potentially transfer beyond the particular study of *E. gracilis* to other scientific reasoning in school and life.

Conclusions

This paper contributes to the small body of work on the impact of practice-based learning on students' understanding of NOS (Rönnebeck et al., 2016). The study was situated in a novel technology-driven activity that combines real data with computational modeling to engage students in evidentiary reasoning in disciplinary meaningful ways. The results indicate that engagement in this activity helped students learn about epistemically rich aspects of scientific work, such as the importance of carefully linking evidence to claims. We believe that these self-formulated insights could be solidified by teachers to help learners becoming participants of scientific conversations who use evidence from real-world data to critically review and evaluate scientific claims.

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