How Does Expansive Curricular Framing Support Productive Epistemological Framing of Computational Modeling Activities?

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Abstract: Computational modeling can be generative for sense making of scientific phenomena. However, because models are abstractions of real world phenomena, making connections beyond them may not be straightforward. In this paper, we argue that expansive curricular framing can support productive epistemological framing of modeling, and influence how learners see their model exploration as relevant to their ongoing investigations. We present an analysis of two groups of undergraduate students investigating relative fitness of low and high mutating bacterial strains in a computational model. We demonstrate that even though the groups are comparable in the quality of work within the model, expansive curricular framing impacts students' epistemological framing of the activity and whether students see ideas from the model as relevant in a broader scope of their investigations.

Introduction

Computational modeling technologies provide generative contexts for sense making of scientific phenomena, enabling students to explore dynamics, and supporting reasoning about mechanisms underlying phenomena (e.g., White, 1984; Wilensky & Reisman, 2006). However, because computational models are abstractions, determining their relevance to other contexts may not be a straightforward task (Goldstone & Wilensky, 2008). This may especially be true when learners investigate pre-built models. Constructing models involves making decisions about abstracting aspects from real world phenomenon to represent (Wilkerson, Gravel, & Macrander, 2014). However, when investigating pre-built models students may be less familiar with underlying abstractions and need help making connections to other contexts. In this paper, we argue that expansive curricular framing (Engle, 2006) can influence whether and how learners see their modeling investigations as relevant to their ongoing inquiry. To make this claim, we present a contrasting case study (Yin, 1994) of two groups of undergraduate students. We argue that even though both groups engage with the model in productive ways, they *frame* the activity differently, and this difference in framing impacts whether and how they see ideas from the model as relevant to their larger inquiry.

Expansive framing and intercontextuality

Expansive framing involves framing the boundaries of a learning context "as being wide-ranging and permeable, increasing the number of contexts that can become intercontextually linked with them" (Engle, Nguyen, & Mendelson, 2011, p. 605). Engle and colleagues (2006; 2011) have argued that expansively framed learning environments help learners see ideas as applicable in a wider range of contexts – creating intercontextualities. We draw on the construct of intercontextuality to explain differences in how students saw a computational modeling activity as connected to a broader scientific investigation.

Epistemological framing

Framing is an individual's sense of "what is it that's going on here" (Tannen, 1993). Epistemological framing is a student's interpretation of an activity with respect to knowledge and learning (Hutchison & Hammer, 2010). For instance, students may frame science class as for learning scientific terminology or for investigating how the world works. These different frames can impact what students do in science class, and ultimately, what they learn. Research has found that student behaviors can provide important cues about their epistemological framing (Scherr & Hammer, 2009). However, these frames are dynamically constructed and sensitive to contextual cues such as teacher moves (Hutchison & Hammer, 2010) and curricular design (Hayes, Wagh & Gouvea, In preparation).

Research goals

This work was done as part of a design-based research (Collins, Joseph, & Bielaczyc, 2004) project called Hybrid Labs. The project aims to integrate physical experimentation and computational modeling for student investigations of complex biological systems. In this paper, we examine factors that enable students to contextualize and connect their model investigations to their ongoing scientific investigation.

Methods

Data collection

The Hybrid Labs curriculum was designed for introductory undergraduate biology labs. Data comes from Years 1 and 2 of the first lab. Lab 1 consisted of 3 3-hour long lab sessions over which students conducted experiments and engaged in model explorations to investigate relative fitness of a low and high mutating bacterial strain. In each year, we collected data in two lab sections, each consisting of about 25 students. In each section, we recorded data from 3 groups: Video recordings of in-group work and Camtasia video data. We also collected students' lab reports, in which they were asked to make a claim for the question, Is it better to be a high mutator or a low mutator?.

Data analysis

Initial analysis involved repeated viewing (Jordan & Henderson, 1995) of videos from Lab 1 of student groups from both years. We discussed initial themes for analysis with the larger research group. We also read through students' lab reports to inspect how students referred to activities from the lab to make an argument. One theme that stood out from this initial work was that though students engaged productively with the modeling activity in both years, fewer students drew on ideas from their model exploration in Year 1 in other parts of the lab. This trend was also reflected in student interviews. This led us to want to explain why this happened.

We selected an exemplary group that engaged most productively in the computational modeling activity each year. We analyzed their Camtasia videos and identified three practices that were salient in students' work: 1) *Manipulating parameters* to create conditions to produce a specific outcome or investigating how parameter changes would impact outcomes; 2) *Attending to* a specific outcome or trend in the populations; 3) *Justifying* or accounting for an observation or prediction. We coded the transcript synced with video to identify occurrences when student utterances reflected engagement in these practices. We also analyzed videos to investigate students' *framing* - how they interpreted the purpose of the activity and where they located epistemic authority (Hammer, Elby, Scherr & Redish, 2005). Based on prior work (Scherr & Hammer, 2009), we identified 3 framing modes: 1) *Sense making mode:* Indicators included authentic engagement with the model such that students engaged in noticing and talking about the model, often accompanied by surprise, confusion, and persistence. Students positioned themselves as agentive in the work. Students' gaze was largely focused on the model in this mode; 2) *Worksheet mode:* Indicators included gazing down at their worksheet for extended periods of time, enacting actions for the sake of filling out the worksheet, and positioning the instructor as being an authority of their investigation; and, 3) *Hybrid mode:* Indicators involved a combination of the two that made it hard to surmise student framing. We coded videos for engagement in these frames. Finally, we analyzed lab reports (N = 3 in G1, and 4 in G2) to inspect whether and how students drew on their model investigations in their discussion of results.

Findings

Our argument is that intercontextuality impacts students' epistemological framing of the activity and whether students see ideas from the model as relevant in a broader scope of their investigations. We compare four aspects of the groups' work: 1) Practices for engaging with the model; 2) Epistemological framing of the activity; 3) Connecting ideas within and across the lab; and, 4) Use of the model to make an argument in lab reports.

Groups' practices of engaging with the model

Both groups engaged with the model in different ways. G1 tried to create specific trends in the model, and changed the parameters multiple times to generate them. They also frequently attended to trends in the model, and tried to explain and justify those trends. G2 asked questions about what would happen when the parameter settings were at particular points (e.g., what would happen when metabolic benefit is high and lethal is low), and they ran six runs for each of their six questions. They ran the model for much longer than G1, and closely attended to trends in the model. However, they did not engage in explaining trends or justifying their predictions as frequently as G1.

Table 1: Practices engaged with in the model (number of occurrences)

	Manipulating parameters	Attending to	Justifying/ explaining
Group 1 (Year 1)	26	21	27

Group 2 (Year 2)	6	20	5

How the groups epistemologically framed the modeling activity

Though both groups engaged productively with the model, we found differences in how they framed the activity. The groups framed their interactions with the model in different ways (See Tables 2 and 3). G1 went back and forth between a worksheet mode and a sense-making mode. During moments of sense-making, their conversations, gestures and affect reflected authentic engagement around their investigation. However, they repeatedly switched back to a worksheet mode, positioning the TA as an epistemic authority (e.g., when they noticed a trend in their model that seemed stable, they asked the instructor if it "counted as stable"). In contrast, G2 framed their work more consistently in a sense-making mode – using the model to understand their experimental results.

Table 2: Epistemological framing of the activity in Groups 1 and 2

	Worksheet mode	Sense making mode	Hybrid mode
Group 1	25.87%	55.97%	1.15%
Group 2	0	98%	2%

Table 3: How Groups 1 and 2 framed the task of recording data from their models

Group 1's Worksheet mode	Group 2's Sense-making mode
(S1 asks as they fill out the worksheet) S1: Do you guys write down the numbers for the past ones? S2: Uhh, I did but I don't really know why. I didn't know what else to write down so. If we need them, I'll, I have them if we need them. S1: (unclear) I might ask you.	*(D & W are asked to share data from their model)* D: Which one do you want me to put in of the three? W: Um the first one, wait not that one, yeah that one. *(Scrolling through captured screenshots of the model)* D: I can put in all 3 A: Yeah because I think all 3 really say a lot

How the groups made connections between the modeling activity and the experiment

Our conjecture is that these epistemological frames were cued by an expansive framing of the modeling activity. Intercontextuality provides opportunities for connecting across contexts. This conjecture is based on our analysis of transcripts - we identified moments when students referred to their experiments or other ideas from class to help make sense of the model. G2 explicitly tied observations and sense-making in the model to their experiment more frequently than G1 (9 times v/s once). This was evidence of intercontextuality – students saw other components of lab as relevant and applicable to ideas they were exploring in the model.

In both years, the model was presented as a tool to make sense of their experimental data. However, in Y1, the connections were not framed explicitly. For instance, the TA introduced the model by simply listing parameters from the model as available features to try out. As a result, the students experienced the model as isolated from their ongoing investigation, and did not tie it back to their experiment. In contrast, in Y2, the TA positioned the model as a way to make sense of experimental data: "I want you to try to model something that is relatively close to the experiment … set up a model that gets at the question that you asked .. [and] really watch those patterns for a while .. and think about how that might relate to some of the data that you actually saw in our experiments." This orienting helped students view the model as a space to make sense of their experiment. Students in G2 repeatedly referenced the experiment during their model investigation, and made attempts to map their experiment and the model.

How students draw on ideas from the model in their lab reports

Of the three students in G1, only one student referenced the model in her lab report. She used her model observations to *validate* her experimental results, specifying conditions in the model that supported her experimental results. However, she did not provide reasoning to support this claim. All students in G2 used their model exploration in their discussion of the investigation. One reason for this was that in Y2, we explicitly asked students to discuss their model explorations in their lab reports. However, students went much further than simply mentioning the model exploration. In lab reports, we found students meaningfully mapping conditions in the simulation with experimental conditions, drawing out similarities and contrasts between the two as mechanisms to explain their observations in each. We also found students in G2 comparing temporal aspects of the simulation and the experiment: Describing how the experiment had been conducted over only a few generations relative to the number of generations that had played out in the simulation. This makes sense given that G2 ran their model for much longer periods of time than G1, which made the temporal dynamics over time salient to them.

Discussion

This work calls attention to the importance of fostering intercontextuality between modeling activities and other components of student inquiry. In our data, both groups engaged in productive practices with the model - they manipulated parameters, attended to and explained how parameter changes impacted survival of the two strains. One might expect that engaging productively with the model itself would help students see the relevance of ideas beyond the model. However, these findings suggested that this was not the case. The model needed to be framed expansively more explicitly for students to be able to see relevance of ideas beyond the model. We tried to create intercontextuality in a few different ways: One, as previously mentioned, the TA explicitly framed the modeling activity as being intended for students to make sense of their experiments. Second, in Y2, we encouraged students to explore the model multiple times through the lab. Students also explored the model as a space for experimental design. The expansive framing created supported students in connecting their work outside the model *into* their model investigations as well as connect ideas from their model to the larger inquiry.

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