A Framework to Integrate Computational Modeling Practices with Three-dimensional NGSS Learning

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Abstract: Computational modeling (CM) supports scientific and computational practices. Little work has examined how CM practices align with the scientific and engineering practices (SEPs) in the Next Generation Science Standards (NGSS). This poster presents a conceptual framework to align five CM practices with SEPs. This framework is being used to develop CM NGSS-aligned curriculum for high school science classrooms in a district. We provide one curricular unit example and discuss design tensions in doing this work.

Introduction and theoretical background

There is consensus that computational modeling (CM) can support integrated learning of science and computing (e.g., Sengupta et al., 2013). However, little work has examined how CM practices align with the scientific and engineering practices (SEP) in the Next Generation Science Standards (NGSS). Translated directly, only two SEPs - "develop and use models" and "using math and computational thinking" - seem relevant. In contrast, studies show that CM supports other relevant scientific practices such as asking questions (e.g., Wagh et al., 2017) and engaging in argumentation from evidence (Berland & Reiser, 2009). Moreover, for teachers, the two present "competing frames of promoting scientific discourse in the classroom, integrating CS for all ideas, and even simply encouraging student agency in using CT for inquiry" (Bain et al., 2020, p.91). In other words, integrating modeling, computational practices and NGSS together in science classrooms is a non-straightforward task. We present a framework that draws on literature to align CM practices with SEPs. We illustrate the framework using an example of a high school Physics curricular unit from the *DC Models* project, a Researcher Practitioner Partnership between a public school district and two universities. We also describe some of the design tensions in doing this work.

Framework and curriculum

Proposed framework to align CM practices with NGSS 3D

In developing this conceptual framework (Table 1), we identified existing CM practices in the literature (Column 1) and mapped them onto modeling and computational thinking practices that they tie to (Column 2). For each CM practice, we then identified SEPs that are manifested in the identified CM practice.

Table 1:
Conceptual framework for Computational Modeling Practices (CMPs)

CMPs	Modeling (M) (e.g., Lehrer & Schauble, 2006) & CT practices (e.g., Sengupta et al., 2013)	SEPs
1: Identify core mechanisms in phenomenon	M: Design & construct models; CT: Abstraction	1; 2; 5
2: Create computational reps of #1	M: Build theories & explanations; CT: Encapsulation	2; 5; 6
3: Read code to interpret relationships/ processes in models	M: Interpret a model created by someone else; CT: Decoding	2; 5; 7
4: Design experiments, make predictions & discover relationships	M: Hypothesis testing & developing theory; CT: Testing units; Using models to understand a concept, find, test solutions	1; 2; 3; 4; 5; 7
5: Validate & extend a model	M: Model verification & validation for theory refinement; CT: Testing & debugging	2; 4; 5; 6; 7

[SEPs: 1: Ask questions; 2: Develop & use models; 3: Plan & carry out investigations; 4: Analyze & interpret data; 5: Use mathematics & CT; 6: Construct explanations; 7: Engage in argument from evidence]

A sample curricular unit: *Can we stop global warming?*

We are using the framework to develop curricular units through co-design with six design partner teachers. For one Physics unit, we focused instruction on the greenhouse effect in part because of its alignment with NGSS DCIs that the partner teachers identified as particularly challenging to visualize [Target DCIs: Energy (HS-PS3-B), Waves (HS-PS4-B); Target CCCs: Cause and Effect, Systems and Systems Models, Energy and Matter, and Stability and Change]. The driving question for the 5-lesson unit was: Can we stop global warming? The first lesson introduced the question and why CM can be helpful in answering it. Students started with a basic model of Earth's temperature, by first identifying heat transfer from the Sun to the Earth and back out to space as a core mechanism (CMP1), then implementing this mechanism within the CM (CMP2). Each day, students were supported in adding more features in the model. By the last day, students chose how to refine and extend their model (CMP5) to try to lower the equilibrium temperature of Earth, as a culminating activity to answer the unit's driving question. This unit was implemented by four teachers with a total of over 150 students. We implemented a pre-post test to assess students' learning of 3D learning along with their learning of CMPs. One teacher's classes, who completed the entire unit and took both pre- and post-tests, served as a pilot study. Preliminary analysis showed positive learning gains. A paired-samples t-test indicates that students scored significantly higher after instruction with the DC-Models unit (Mean(pre) = 2.188 ± 1.243; Mean(post) = 3.439 ± 1.570), $t(56) = 5.066$, $p < .001$.

Discussion: Design tensions and future research

Implementing NGSS instruction can necessitate an epistemic and pedagogical shift in the student and teacher role in the classroom (e.g., Kawasaki & Sandoval, 2020). Introducing CM further accentuates this shift. Students and teachers need space and time to negotiate between their goals and the new practices, which can be challenging. Moreover, fostering student autonomy while providing adequate support for students and teachers with minimal exposure to CM is a design tension. Our teachers have argued for structured guidance in worksheets to enable student autonomy. Taking on the role of providing the guidance led one teacher to express concern about being, in their words, a "sage on the stage". However, we are grappling with tensions in creating a "sage on the *page*" by providing too much guidance that may stifle autonomous investigations by students. This makes it challenging to construct open-ended activities and support productive discourse where the class community collectively engages in scientific inquiry. Moving forward, we are empirically testing the framework to examine student data while engaging in these CMPs to look for evidence of the proposed alignment in Table 1, and examining how these CM practices support integrated NGSS learning. Our ultimate goal is to help the field better understand the relationships between CM practices and NGSS 3D instruction.

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