How Teachers Support Student Computational Thinking Practices

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Abstract: Computational Thinking (CT) is increasingly being targeted as a pedagogical goal for science education. As such, researchers and teachers should collaborate to scaffold student engagement with CT. We interviewed two teachers who implemented a unit using a dynamic modeling software to examine how teachers are supporting student engagement with CT through modeling practices; they supported modeling through preliminary activities, conducting demonstrations, and engaging students in model revisions through dialogue.

Keywords: Computational Thinking, System Modeling, Design Based Research

Introduction

Computational thinking (CT) describes the cognitive processes necessary to deconstruct a problem in such a way that it can be solved recursively by a separate information-processing agent (such as a person or a computer) (Wing, 2006). Although computer science and CT have been key drivers of scientific development and innovation for several decades, CT has only been recently emphasized as a major pedagogical goal through new curricular standards (Grover & Pea, 2017). As CT is being adopted into science education standards on a global scale, there is a growing need to understand how teachers foster CT in science classrooms (Grover & Pea, 2017; Kale et al., 2018). To support teachers in implementing CT practices in their classrooms, designers and researchers need to develop new technology, curricula, and pedagogical approaches that provide opportunities for students to engage in CT practices. We have developed a new conceptual framework to scaffold our curriculum development called "CT through Engagement in System Modeling" (Damelin, Stephens, & Shin, 2019). This conceptual framework emphasizes the synergy that occurs when CT is supported by systems thinking (ST) in a system modeling curricular context. These CT and ST through modeling practices include: defining the phenomenon to model, considering modeling approach, defining the boundaries of the system, designing and constructing model structure, testing, evaluating, and debugging model behavior, and using model to predict behavior of phenomenon.

Study context and research question

We designed and implemented curricula that engage students in both CT and ST using a dynamic modeling software. Our modeling tool allows students to create conceptual models, generate semiquantitative data from those models, and compare their theoretical data to experimental data. We partnered with two high school chemistry teachers [Mr. S and Mr. B] at a midwestern STEM school ($N \approx 100$) to implement a two-week unit (7 class periods, 80 minutes per class). The phenomenon the students explored was how an oil tanker could have been crushed by standard air pressure. Operating within a design-based research paradigm, we are interested in how teachers foster student engagement in CT, ST, and modeling. Our research question is, "What pedagogical strategies do teachers use that effectively engage students in CT and ST through modeling practices?"

Methodology

After the unit's conclusion, we conducted semi-structured 25-minute interviews with both Mr. S and Mr. B using video conferencing. We then conducted a two-part thematic analysis of the interview transcripts by isolating and sorting passages that discussed teacher strategies for supporting student engagement with specific modeling practices. We then reread these passages in their new context to discover converging themes about the pedagogical practices used by the teachers to foster student engagement with CT and ST through modeling practices.

Major findings, conclusion, and implications

During the interviews, both teachers discussed pedagogical strategies they utilized within this unit to support student engagement with our modeling practices. The modeling practices they mentioned include: defining the boundaries of the system, designing and constructing model structure, and testing, evaluating, and debugging model behavior. Students define system boundaries by identifying which components of the model are necessary to understand the phenomenon; students construct model structure as they define and revise relationships between model components; and students test, evaluate, and debug model behavior when they run the model to generate data to examine the validity of their models and make revisions to reflect their new conceptual understanding.

Defining system boundaries

To support students in defining system boundaries, Mr. S had his students "write down their initial ideas and then they do a little bit more paper-pencil modeling first before they actually launch into this modeling program and the dynamic modeling approach, so [that] they can get a better idea of what the system boundaries are." By engaging in paper-pencil modeling before interacting with the modeling software, the students had the opportunity to explicitly consider which variables were critical to understanding the phenomenon and which ones were irrelevant. Paper-pencil modeling also helps students visualize their conceptual understanding of the phenomenon before engaging in the more abstract aspects of system modeling with the modeling software.

Constructing model structure

The teachers engaged students with constructing model structure through preliminary, pre-software "warm-up" activities, including a decontextualized scenario where the students had to determine and graph the appropriate functional relationship between car accidents and the number of cars on the road. Mr. S stated, "This time something we tried and we think it worked really well was giving them scenarios and having them pick out which type of relationship they think it would be. Inside of the warm-up."

Testing, evaluating, and debugging

The teachers supported students in testing, evaluating, and debugging the models by conducting in-class demonstrations that showcased relationships between key variables. As Mr. S. noted, these demonstrations "allow them [students] to go back and look at their models again and maybe debug the behavior that they saw in the demonstration, but their models are not supporting. Okay and then they will go back, make a revision and keep that cycle going." Both teachers also encouraged model revision through discourse moves that helped students consider the weaknesses of their models and whether or not their models were supported by real-world data.

> Mr. S: I was sitting down with a couple of groups today and they were explaining to me exactly how they wanted it to work and they were seeing how it wasn't working. And so we had a conversation about "How do we get from where you are right now to where you know it should be? What else do we have to include or what do we have to play with? Because you are saying that these two relate, but what are you not doing?" And then they were able to say, "Oh. There's no actual link between these two, other than the final variable. We know that it has got to link these two before it can actually impact that one."

Discussion

Findings from the teacher interviews suggest that teachers can support student engagement with several modeling practices within a system modeling unit by having students construct paper-pencil models before they open the dynamic modeling program, observe demonstrations of key aspects of the phenomenon they are modeling, and engage in Socratic dialogue about their model behavior. Our findings respond to the need to examine CT from a pedagogical content knowledge perspective as proposed by Kale et al. (2018) by providing new insights into how teachers can promote student engagement with CT through modeling. However, a more detailed analysis of classroom videos and student models will need to be conducted to evaluate the efficacy of these pedagogical techniques on enhancing student engagement with CT and ST through modeling practices. As CT is being adopted into science education standards on a global scale, it is becoming apparent that students need additional context-specific support from teachers to fully engage in this practice (Grover & Pea, 2017; Kale et al., 2018). Therefore, it is important that researchers continue to identify and evaluate effective pedagogical strategies for CT so that more students have opportunities to participate in CT practices in their science classes.

References

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