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Computational Thinking for Using Models of Water Flow in Environmental Systems: Intertwining Three Dimensions in a Learning Progression

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Tweet: How students make sense of systems and system models influences their engagement in computational thinking and their understanding of how water flows through environmental systems.

Audience: Curriculum designers; Assessment developers; Environmental educators; Secondary science teachers

Key Points

- The science and engineering practice of computational thinking is helpful for understanding models of groundwater contamination or urban flooding.
- Student understanding of the crosscutting concept of systems and system models plays a role in the development of computational thinking and understanding of disciplinary core ideas related to water moving through environmental systems.
- At higher levels on the learning progression, student performance more tightly intertwines the science and engineering practice, crosscutting concept, and disciplinary core ideas.

INTRODUCTION The *Framework for K-12 Science Education* emphasizes the intertwining of three dimensions of student learning performances: science and engineering practices, crosscutting concepts, and disciplinary core ideas. Yet, there are few empirical examples of how intertwining these three dimensions facilitates learning. In this project we designed curriculum units that engaged students in using computational models of groundwater contamination or urban flooding to learn about computational thinking (science and engineering practice), systems and systems models (crosscutting concept), and water flow through environmental systems (disciplinary core ideas). We analyzed student responses to post-assessments to characterize levels of student proficiency along each dimension and the relationships among the dimensions in student performances.

FINDINGS We identified three levels of a learning progression that characterizes differences in student learning performances. At the lower level, students' learning performances attended primarily to the visible aspects of models and approached the models as simulations only. At this level, the three dimensions remained separate. At the next higher level, students used the computational models to solve real-world problems, such as finding a solution to clean up groundwater contamination. These students' learning performances suggest that the computational thinking dimension and the system and system models dimension were beginning to integrate. However, learning performances at this level showed that students were not yet able to use hydrologic disciplinary core ideas to explain how the models worked. At the upper level, students used computational thinking processes and principles of systems modeling and hydrology to explain how the computer models worked to predict water flow, suggesting that all three dimensions were intertwining in student learning performances.

TAKEAWAYS Our research shows how the crosscutting concept of systems and system models played a role in students' learning to engage in computational thinking practices and then in their development of an understanding of disciplinary core ideas about water. This finding points towards the importance of recognizing the separateness of the dimensions at the lower performance level and attending to how the dimensions come together as students gain experience. Our research also suggests that becoming more competent in computational thinking is not simply a matter of getting better at computational thinking; computational thinking is shaped by the context in which it is used. What we saw change across the learning progression was students' understanding of the nature of what they are doing when they engage in computational thinking and for what purpose. Finally, we argue that the ability to intertwine computational thinking, systems and systems models, and principles of how water moves through environmental systems is essential for making sense of environmental issues that have relevance to one's life, such as groundwater quality or urban flooding events.

Comp Hydro curriculum units are available at http://ibis-live1.nrel.colostate.edu/CompHydro/.