CTSIM: A COMPUTATIONAL THINKING ENVIRONMENT FOR LEARNING SCIENCE USING SIMULATION AND MODELING

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Science education in K-12 classrooms has been a topic of growing importance. The National Research Council framework for K-12 science education includes several core science and engineering practices: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, and constructing explanations and designing solutions. Several of these epistemic and representational practices central to the development of expertise in STEM disciplines are also primary components of Computational Thinking (CT). CT involves formulating and solving problems, designing systems, and understanding human behavior by drawing on the fundamental concepts of computer science. Specifically, CT promotes abstraction, problem representation, decomposition, simulation, and verification practices. Thus it is not surprising that CT is included as a key feature in NRC's K-12 science education framework. In fact, several researchers suggest that programming and computational modeling can serve as effective vehicles for learning challenging STEM concepts.

In spite of the observed synergies between CT and STEM education, empirical studies have shown that balancing and exploiting the trade-off between the domain-generality of CT and the domain specificity of scientific representations, presents an important educational design challenge. To address this gap in synergistic STEM and CT learning, we have developed a computer-based learning environment called CTSiM: Computational Thinking in Simulation and Modeling for K-12 science learning using a computational thinking approach. CTSiM provides an agent-based, visual programming interface for constructing executable computational models and allows students to execute their models as simulations and compare their models' behaviors with that of an expert model.

In this talk, I will first present key design principles and their translation to details of the CTSiM architecture. In an initial study with 6th-grade students in a middle Tennessee public school, students showed high pre-post learning gains and a good understanding of the basic science concepts. However, students also faced a number of challenges while working with CTSiM. We discuss the challenges that students faced while working on physics and ecology units using CTSiM.

Further, I will also present a framework for developing adaptive scaffolding to help students overcome their difficulties, while learning and building their models of science phenomena in the CTSiM environment. To interpret students' learning, modeling, and model verification behaviors as they work in CTSiM, we have developed a hierarchical task modeling and strategy modeling scheme that can be directly leveraged for online interpretation of students' activities in the learning environment. The strategy model complements the task model by describing how actions, or higher-level tasks and subtasks, can be combined to provide different approaches or strategies for accomplishing learning and problem-solving goals. The task and strategy modeling in combination with coherence and effectiveness metrics defines our approach to tracking and analyzing students' learning and problem solving behaviors in OELEs. We then describe an application of this framework in a Computational Thinking using Modeling and Simulation (CTSiM) environment -- an OELE that supports synergistic learning of science and computational thinking (CT) for middle school students. We discuss the learner modeling scheme for the CTSiM environment, and then describe how the learner model forms the basis for providing adaptive task and strategy based feedback to students using a contextualized, mixed initiative conversational dialog framework. A recent controlled study run in a 6th grade classroom showed that the experimental group that received adaptive feedback outperformed the control group (no feedback) in domain and CT learning gains, the ability to construct correct models, and in using strategies for effective learning and problem solving.