Integrating Computer Science for All and Physics for All in Secondary Education:
An Exploration of Bootstrap and Modeling Instruction in Physics First Courses

The United States lags behind other nations in student achievement in science, technology, engineering, and mathematics (STEM). Despite the urgent need for a workforce skilled in computing and computational thinking, relevant courses are not equally accessible to students from all groups, especially students from racial and ethnic minorities and low-income groups. Integrating computing and computational thinking in courses within the STEM disciplines, like physics, is one approach for increasing students' accessibility to computing while supporting deeper learning of science disciplines. Many school districts have adopted standards that call for students to create, refine, and use models and computational thinking –central practices for scientists and engineers—to support science learning. However, teacher preparation and engaging curricula to support such synergistic learning is lacking. Of those teachers and curricula that do incorporate computational modeling in physics, many occur in upper-grade, calculus-based physics courses. Integrating computational modeling in only upper-grade physics courses may serve to widen the achievement gap, because Black, Hispanic, and female students are disproportionately underrepresented in these courses. Investigators of this project hypothesize that the use of computational modeling in the context of lower-grade, algebra-based "Physics First" courses improve underrepresented students' access to opportunities to learn and apply computational thinking practices in service of learning physics and solving physics problems. Led by investigators affiliated with the American Association of Physics Teachers, this project will engage teachers in professional development that enables them to effectively plan and implement classroom instruction in algebra-based Physics First courses that integrates computational thinking through two existing, widely used approaches and accompanying resources—Modeling Instruction for physics and Bootstrap for computational modeling. Participants include 60 high school Physics First teachers and students in their Physics First courses, who will be more demographically diverse than that students historically enrolled in standalone computer science courses or upper-grade physics courses. The research will generate new knowledge about how the integration of Modeling Instruction and Bootstrap supports teacher and student growth in confidence and competence in physics concepts and physics problem solving through computational modeling. The resulting products of the research and development will be shared with more than 8,000 high school, community college, and 4-year college members of the Modeling and Bootstrap practitioner communities.

The STEM+Computing Partnership (STEM+C) program seeks to advance multidisciplinary integration of computing in STEM teaching and learning through applied research and development across one or more domains; integration of STEM in computer science; and broadening participation in computer science. Investments are made in critical areas of pedagogy, pre-service and in-service teacher professional development. Annually this project will recruit 20 Physics First teachers who are experienced at using Modeling Instruction to participate in Bootstrap professional development and a scaffolded process for designing computational modeling modules for their physics first classes. Each year, two master teachers selected from the cohort will further develop and refine the modules, which will be tested by all teachers in the cohort. Project staff will convene teachers monthly for online discussion about the modules and their implementation, to support teachers' practice and to inform the refinement of both the professional development and curricular resources developed through this project. The design-based research will explore how teachers' participation potentially affects their understanding of physics and computational thinking and their competence in integrating computational modeling in their physics curriculum and instruction. The research will also explore how instruction that integrates computational modeling in physics influences students' understanding of physics and computational thinking and abilities to use computational modeling to solve problems in physics. Data sources will include teacher and student tests, surveys, interviews, teacher lesson plans, and student work products from the use of the Bootstrap tools. Implementation logs and classroom observations will be collected during project team site visits to understand teachers' use of the curricular modules. Project team and advisory board members will disseminate findings to their respective professional associations and networks, including the American Association of Physics Teachers, American Modeling Teachers Association (AMTA), STEMteachersNYC, and stakeholders of the Bootstrap user community. Findings will also be shared by more traditional means, such as papers in peer-reviewed journals and conference presentations. Efforts will be made to incorporate the modules produced in this study into the more than 80 Modeling Instruction workshops offered each year through the AMTA.