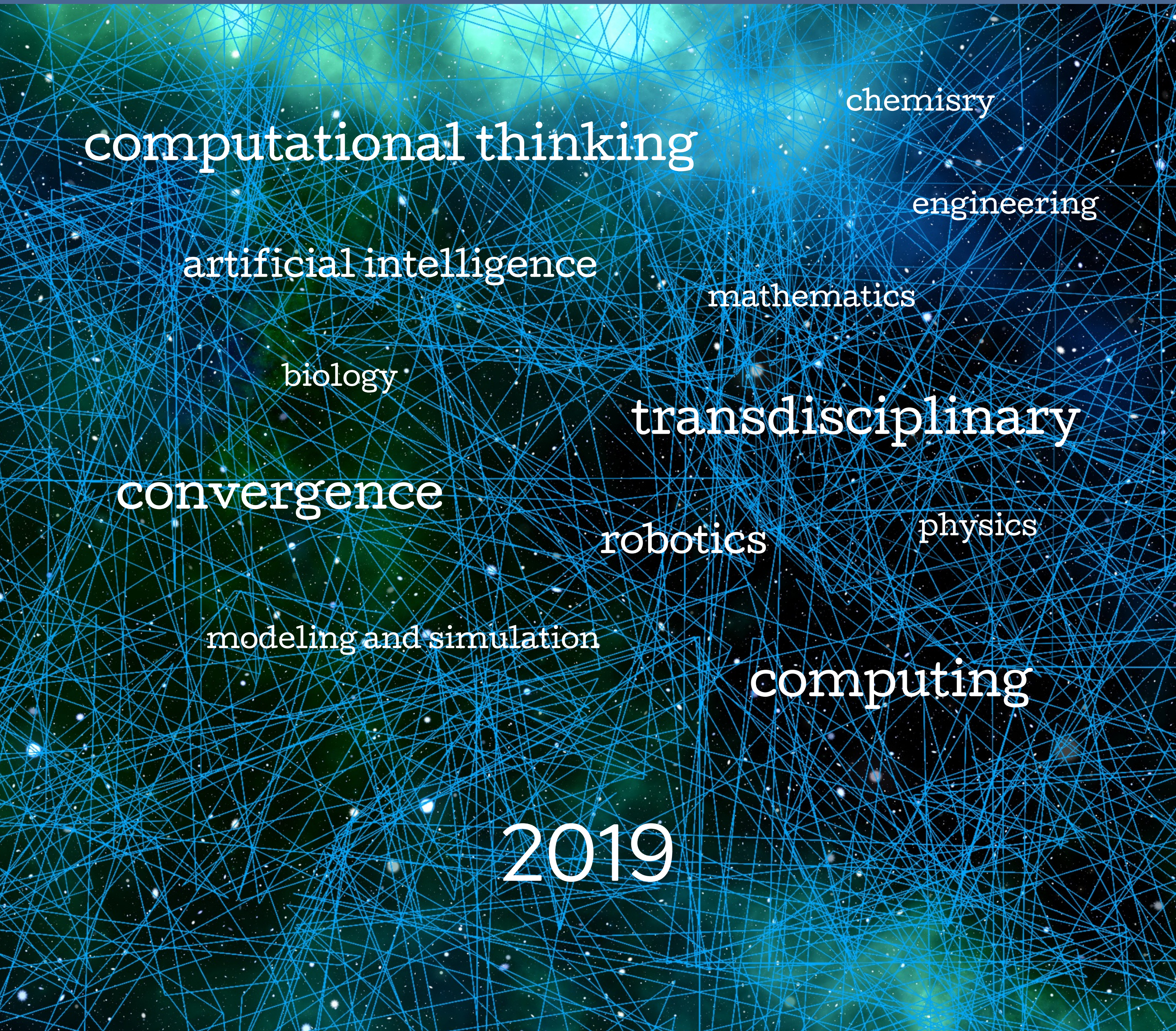
STEM+COMPUTING PROGRAM

Reconceptualizing Learning and Teaching: STEM Integration in the Age of Computational Thinking

STEM+C PROJECTS BOOKLET



STEM+ C PROGRAM
PROJECTS BOOKLET
2019

NATIONAL SCIENCE FOUNDATION

STEM+C Awardee and Project Description Booklet

As computing has become an integral part of the practice of science, technology, engineering and mathematics (STEM), it is imperative that students be exposed to the role of computation and computational thinking within disciplinary problem solving, and learn the essential concepts, methods, and wide-ranging creative uses of computation for real-world application. With the understanding that computational thinking involves more than the use of computers, STEM+C contributes to the discovery of the nature of computational thinking itself and how it is operationalized within STEM fields and increasingly in interdisciplinary research and other domains.

Because of the powerful innovation and application of computing in the STEM disciplines, the STEM + Computing (STEM+C) program is investing in research studying how to best prepare students from the early grades through high school in the essential skills and core competencies needed to participate and succeed in the increasingly computationally-intensive STEM fields. The program's research trajectory also contributes to the understanding of interdisciplinary and transdisciplinary approaches to STEM teaching and learning in perK-12, associated with the increasing convergence of disciplines. This is particularly important in the key areas of described in the National Science Foundation's *Big Ideas for the Future* related to Convergence Research, Harnessing the Data Revolution, and the Future of Work at the Human-Technology Frontier.

In its awards, STEM+C requires computing and computational thinking be well-integrated into existing STEM curricula or activities to encourage interdisciplinary, integrated STEM teaching and learning, and the study of the effectiveness of applying computational approaches across a range of disciplines and real-world applications within those disciplines to build evidence for new pedagogical strategies that enable students, in and out of school, to learn the exciting and creative modes of scientific exploration made possible by advances in computation.

The *STEM+C Awardee and Project Description Booklet* is a sample of STEM+C awards building evidence on student learning, pre-service teacher education, and professional development of teachers that afford excellent instruction for the preparation of students in disciplines and subdisciplines across areas of artificial intelligence, chemistry, physics, mathematics, cognitive Science economics, education research, engineering, geological and Earth science, computer and information science, health science, history, political science, psychology, and sociology.

Integration of computing and computational thinking within other STEM disciplines may well have profound effects on preK-12 STEM education—reflecting the increasing role of computational approaches and computational thinking in the STEM disciplines. It is intended that outcomes of STEM+C projects strengthen the STEM workforce with the knowledge and capacity to confront the current and emerging challenges in computational and data-enabled science.

STEM+C Computing is a program of the Division of Research on Learning in Formal and Informal Settings, Directorate for Education and Human Resources, National Science Foundation, 2415 Eisenhower Avenue, Alexandria, VA 22314

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A Logic Programming Approach to Integrating Computing with Middle School Science Education (DRL-1901704)

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Hypothesis

Principles and methodologies underlying the Computing provide a natural and effective integration of the teaching and learning of Computing, STEM and disciplines beyond.

Approach

Logic Programming (LP) paradigm including its modeling methodologies provides a way to seamlessly integrate Computing and STEM teaching and learning by developing computer models for STEM problems.

- LP provides a unified treatment of the fundamental skills in STEM and Computing thanks to *Logic*, a root of LP, which forms the basis for learning and problem solving in all STEM disciplines.
- The LP modeling methodology allows a natural and seamless connection of subject-matter concepts and reasoning to computer model development

Team

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Findings

LP based integration demonstrated effectiveness in our preliminary studies.

- *Students*. 96 6th graders and 71 7th graders use 8-session long modules. Students' abstraction skills are improved significantly, and 7th graders' knowledge in physics improves significantly. LP based integration is acceptable to students.
- *In-service teachers*. Two teachers with teaching experience in math and technology respectively. Five-day professional development workshop. Teachers demonstrated significant improvement in terms of the knowledge in Chemistry and in Computing (both *abstraction* and *programming*). Teachers strongly agree the power of LP in providing a unified integration of Computing and Science. They see the values of LP based integration in improving students' learning in both Computing and Science. They also perceive many possible ways to integrate Computing and other topics or subjects (e.g., mathematics) using LP.

References

Yuanlin Zhang, Jianlan Wang, Fox Bolduc, William G. Murray: *LP Based Integration of Computing and Science Education in Middle Schools*. ACM First Conference on Global Computing Education (CompEd) 2019

SPICE

Science Projects Integrating Computing and Engineering

A Study of a Technology-enhanced Curriculum Integrating Science, Engineering Design, and Computational Modeling to Achieve Synergistic Learning with Elementary Students

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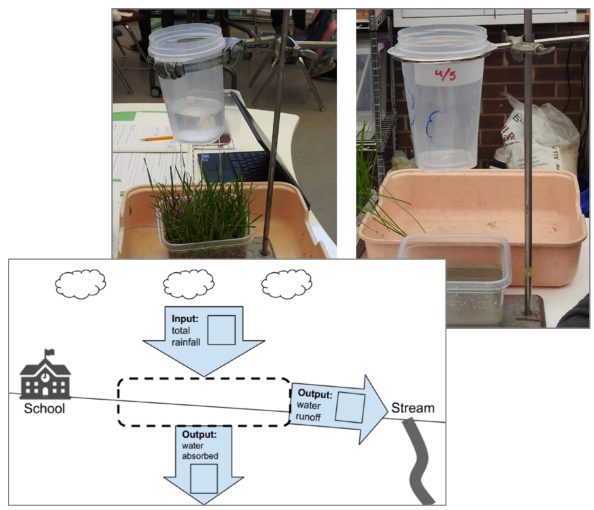
DRL-1742195
spiceprojects.org

Development goals

- Curriculum materials aligned with upper elementary NGSS PEs in earth science and engineering
- A computational modeling environment enabling students to model systems and develop, test, and refine engineering solutions
- Embedded assessment tasks informing teachers about their students' progress toward the PEs
- Educative supporting resources that help teachers successfully implement the curriculum unit

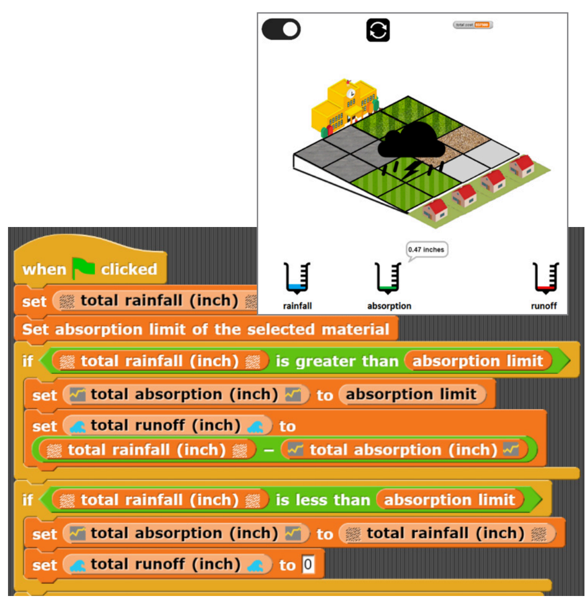
The Water Runoff Design Challenge

The 4-6 week unit challenges upper elementary students to design school grounds in a way that minimizes urban water runoff while meeting design constraints on cost and wheelchair accessibility. Students investigate the relationship among rainfall, water absorption, and runoff, develop a conceptual runoff model, and generate initial designs. Students then use a computational environment to program a runoff simulation and use it to test, compare, and iteratively refine their designs. The unit emphasizes a systems perspective throughout, prompting students to model inputs and outputs conceptually, mathematically, and computationally.



Preliminary Findings

In a pilot study (N = 88), students made significant gains on a pre/post assessment measuring their engineering design proficiency in the context of water runoff. We determined how well students' designs in the simulation environment met the three design criteria. Our analyses indicate that students' ability to discern better design solutions in the simulation environment is strongly indicative of their pre/post improvement on comparing design solutions. Analyses of log files inform how we can characterize the changes students make between design iterations (Zhang et al., 2019).



Zhang, N., Biswas, G., Chiu, J. L., & McElhaney, K. W. (2019). Analyzing Students' Design Solutions in an NGSS-aligned Earth Sciences Curriculum. Proceedings of the 20th International Conference on Artificial Intelligence in Education, pp. 532-543. Chicago, IL. https://doi.org/10.1007/978-3-030-23204-7

NSF | University of Virginia Curry School of Education | Vanderbilt School of Engineering | SRI Education

Computer Science Integrated with Mathematics in Middle Schools (CSIMMS)—DRL 1640039

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Computer Science Integrated with Mathematics in Middle Schools (CSIMMS) is a **Track 1 Exploratory Integration (EI)** project under the leadership of Florida State University (PI: Yuan, Co-PIs: Andrews-Larson, Granger, Southerland, Whalley) that brings middle-school mathematics teachers together with university computer science (CS) faculty and STEM education faculty to design, develop, and test modules in which CS is integrated into instruction of middle-school general-mathematics courses. The development of CS modules is guided by the principles of Design-Based Research (Design-Based Research Collective, 2003). Over three years, middle-school teachers from different school contexts (urban, high needs, etc.) participate as members of the design team and trial testers of the CS modules. The **goals** of this project are to examine what it takes to implement prototype CS modules appropriate for the middle-school grades 6, 7, and 8, developed through Design-Based Research and to determine student outcomes related to integration of these modules into middle-school general-mathematics courses. The results of this project could provide preliminary proof of concept evidence for inclusion of such modules into mathematics instruction. The **objectives** of the project are to: (1) Employ Design-Based Research for the development and implementation of CS modules for general mathematics courses at each middle-school grade level (6, 7, and 8); (2) Engage teams of middle-school mathematics teachers, CS university faculty, and STEM educational researchers in collaborating in the design and development of these CS modules; (3) Examine the effectiveness of the CS modules for teaching selected Common Core aligned mathematics content and practices; (4) Examine the effectiveness of the CS modules for teaching basic, foundational CS content and practices; (5) Examine how teacher thinking and beliefs about mathematics learning and their familiarity with the math/CS modules shape the ways in which they enact these modules and their impact on student learning, and (6) Explore the capacity building necessary for schools to successfully integrate CS modules into mathematics instruction at the middle-school level.

The **Intellectual Merit** is closely related to the **Broader Impacts** of the project and they arise from determining (1) the effectiveness of CS modules integrated into general mathematics classes at the middle school level in engaging a diverse group of students in successful participation in CS and mathematics and (2) school and teacher capacity for CS instruction. It is hoped to impact society more broadly by providing fully developed and pilot tested CS modules for integration into middle-school general-mathematics courses. The project has the potential to contribute to increasing the number and diversity of students interested in and prepared for high-school and post-secondary work in CS and mathematics.

The first two years of this Design-Based-Research project focused on development, classroom pilot testing, and post-testing revision of the CS modules. Data were collected that informed the revision of the modules and the development of student assessments of mathematics knowledge and CS knowledge related to the specific modules. School and teacher challenges for this type of integration were documented. Design Principles for integrative math/CS curriculum modules are in development. Final classroom testing of and student data collection on all revised modules will follow in the upcoming academic year. Data will also be collected focusing on understanding the differences in implementation and student learning for teachers with differing amounts of familiarity with the math/CS modules. Finally, data collection on teacher and school capacity will continue.

Investigating the Impact of a Sustainable Computer Modeling Curriculum on Mastery of Core Biology Concepts and Computational Thinking in Secondary School Students

NSF Award #1742373 - Hofstra University - stemc.hofstra.edu

STEM+C

PROJECT OBJECTIVES

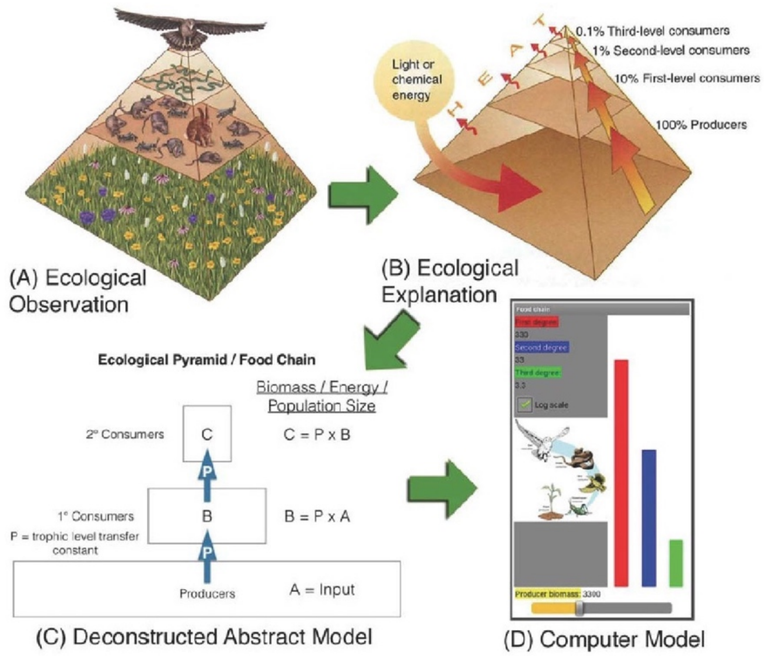
- Integrate computational thinking into a high school biology curriculum by teaching students to code apps to solve biology problems and model biological processes.
- Study the impact of the computationally enhanced curriculum on student mastery of biology and attitudes toward careers in computation and STEM.

CODING PLATFORM

Students are coding using MIT App Inventor, an intuitive, block programming environment that allows anyone to build fully functional apps for smartphones and tablets. Students can use the apps they create to help them master concepts in the biology curriculum.

MIT App Inventor

COMPUTATIONAL MODELING IN BIOLOGY - FROM OBSERVATION TO ABSTRACTION TO COMPUTER MODEL



CURRICULUM MODULES - Developed in Consultation with our High School Biology Teacher Partners

Measurement / Experimental Design

- Metric conversion calculator app
- Measurement calculator app
- Total magnification calculator app
- Field of view calculator app
- Random sample simulation app

Biochemistry, Reactions, Feedback Systems

- Enzyme reaction rate simulation app
- Blood sugar level simulation app

Genetics, Evolution & Natural Selection

- Antibiotic / pesticide resistance simulation app
- Chromosome number simulation app
- DNA – RNA – Protein translation / transcription app
- Genotype / phenotype calculator app

Ecology: Energy Flow & Populations

- Food web simulation app
- Energy pyramid simulation app

Differentiated Instruction - 3 Skill Levels

Each curriculum topic can be taught at three levels of coding skill, allowing different learners to acquire appropriate computational skills while learning the same biology concepts.

Beginner

- Students are given a fully coded app and asked to modify its appearance and functionality.

Intermediate

- Students are provided with the design of the app and the code but have to assemble the code blocks to make the app function.

Advanced

- Students are provided with design parameters and must design and code the app themselves.
- All levels include opportunities to learn new skills.

ASSESSMENT

To assess the impact of the modified curriculum on students, data are being collected from multiple high school biology classrooms in six school districts to measure attitudes toward STEM and computer careers, application of computational thinking to problem solving, and mastery of key concepts in the biology curriculum.

Hofstra University Project Team

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HOFSTRA UNIVERSITY

DRL 1840933

Learn.Design.Compute with Bio

A Workshop for Connecting Computational Thinking with Synthetic Biology Applications in K-16 Education

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Synthetic biology is an emerging field focused on understanding, re-designing and constructing new biological systems in precise and controlled ways and has resulted in many commercially available products and applications. By standardizing DNA sequences to deliver genetic information, synthetic biology reduces the complexity of the biological design process and provides various kinds of abstraction, modularity, and assembly methods that connect well to computational thinking. 21st-century STEM education will teach students about the opportunities and challenges associated with synthetic biology in a world that increasingly harnesses this biotechnology to solve problems in healthcare, energy, and the environment.

We used a multi-pronged capacity-building approach consisting of: research workshops, mentoring meetings,public events, and dissemination, that brought together key researchers, educators, designers and policy makers for discussions around synthetic biology in K-16 learning. In workshop discussions in April 26, 2019 at the University of Pennsylvania, we focused on the following impact areas for examining the relationships between computational thinking and synthetic biology: **Learning:** What do we need to know about students' prior understanding at different age levels? What are promising pedagogies? What are tools (interviews, surveys, etc) for assessment? How much do students need to know about biology before engaging with biodesign? **Teaching**: What are appropriate activities that are accessible and feasible for K-16 students? **Tools**: What kind of laboratory and simulation tools do we need to design to support biodesign activities? **Spaces:** Where are learning opportunities for biodesign in classrooms, community labs and competitions? **Ethics**: What are critical issues in biodesign? How best to engage students in discussions? **Safety and Security:** What are critical issues in biodesign? How best to engage students in discussions? We hosted a public panel to engage the larger community in these discussions. The workshop also included mentoring meetings with graduate students and early career researchers recruited via national and international searches.

In coming months, we will summarize insights gained in workshop discussions by (1) identifying key *issues* on how synthetic biology and computational thinking can be taught and learned in K-16 education, in particular how it relates to educational content and contexts in science and computer science education; (2) examining potential *connection* points between synthetic biology and ethical concerns; and (3) developing a *framework* that will allow researchers to articulate possible interactions between biodesign in their future research design, and applications. For more detail on the workshop meetings, panel discussions and upcoming report, please see **http://learn.design.bio**

Adaptive Training of Representational Flexibility in STEM+C for Autistic Adolescents

(NSF Grant # 1837917)

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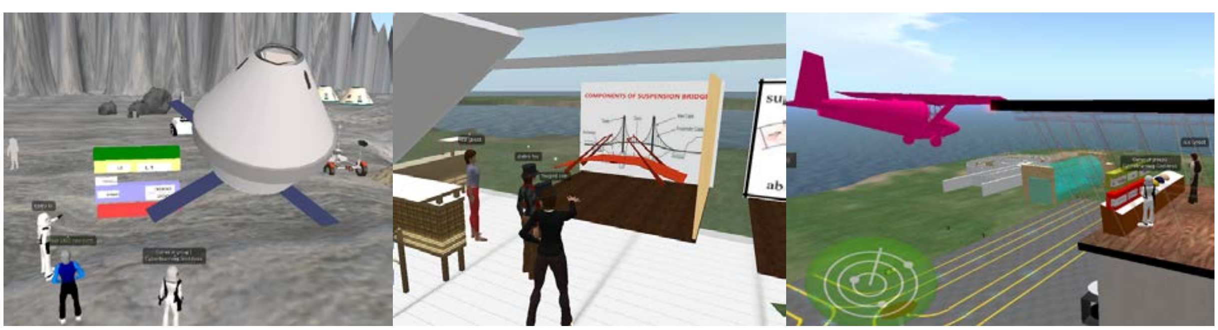
Need: Representational flexibility is critical for the practices of computational thinking and problem solving across STEM and computing domains. However, the development and enactment of representational flexibility is effortful and demanding for most learners, but particularly so for students with autism spectrum disorder (ASD).

Goal: This project aims to study individualized training of representational flexibility for STEM and computational reasoning and problem solving among adolescents with ASD, hence addressing a significant barrier to college enrollment of this learner group who otherwise have the potential to become future sources of STEM talent.

Approach: Researchers utilize 3D virtual reality (VR) with body sensory technologies to create an adaptive, representational flexibility training program that helps participants learn how to design and code simulations and games in a 3D virtual-reality context. This program, called Force and Motion-Adaptive Representation (FM-AR), will facilitate participants' ability to select, connect, convert, and construct multimodal representations of physics and mathematics problems while practicing and experimenting with computational concepts during VR-based simulation design and programming.

Benefits: Via a design-based, mixed-method research approach, this project will generate a conceptual and design framework governing the design and research of a STEM+Computing learning environment that scaffolds representational flexibility for a heterogeneous learner group. It will address a critical issue facing the inclusive STEM+C learning: the lack of adaptive and engaging interventions that promote STEM+C performance and transfer for learners with special needs.

Preliminary evidence: An exploratory analysis indicated an instant, stable, and increasing trend in participants' acquisition of the representational flexibility competency during the FM-AR activities.



“CT-ifying” the High-School Science Curriculum to Broaden Participation in Computational Science
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Project Overview

While computing has dramatically transformed science and engineering research and practices, it remains a separate and distinct area of study in almost all pre-college education contexts. In many schools, students are only exposed to computational thinking (CT) in elective computer science courses. By teaching computing and STEM topics separately, we miss a critical opportunity to prepare young people, in particular those who have been historically disenfranchised, to approach problem solving and scientific inquiry in computationally sophisticated ways and to see computing and STEM as synergistic and integrated. There is need for further elaboration on the characterization of CT-STEM to encompass a wider range of computational tools and methods. There is also a need for more curricula covering a variety of subject areas in high school science curriculum. Thus, goal of this project is to design units that engage students in computational practices while covering high school science curriculum.

Goals and Objectives

The project will pursue the following five objectives:

(1) seamlessly integrate data analysis, data visualization, and system dynamics with NetLogo and NetTango and offer these updated tools through our web-based platform
(2) build units that cover more of the high school science curriculum and incorporate practices for developing algorithms, data mining, data visualization, and designing/building agent-based and system dynamics models
(3) develop assessments that evaluate students on these practices;
(4) test units and assessments in classrooms by collecting student response data through our web-based platform
(5) investigate students’ engagement in computational thinking practices and characterize the competencies that they bring to their learning and how their practices develop over time

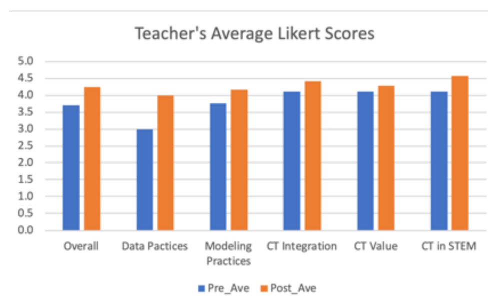
Research Overview

The objective of this project is to increase students’ interest, confidence, and skill in CT-STEM practices and explore how computational representations support significant shifts in the ways that students learn and practice science. The project investigates three research questions:

(1) To what extent do our CT-STEM student materials and professional development increase students’ and teachers’ interest and confidence in computational thinking and problem solving in STEM?
(2) How does the integration of various computational tools support student development of CTSTEM practices across several high school science subjects?
(3) A. What is the character of the informal competencies students draw upon when they engage in CT-STEM practices?
B. How do students use these competencies synergistically over time to engage in CT-STEM practices more productively?

Evidence

With research question #1 in mind, in the first year of this grant, our team has designed and implemented the first iteration of the CT-STEM Summer Institute with 8 local high school science and math teachers. During the institute, teachers worked with the Northwestern CT-STEM research team to co-design “CT-ified” math and science units. This collaborative curriculum co-design process resulted in increased comfort with CT-STEM practices, specifically computational data practices and computational modeling practices.



Project Team: Uri Wilensky, PI; Michael Horn, Co-PI; Amanda Peel, Postdoctoral Scholar; Sally Wu, Director of Curriculum Development

Assessing Computational Thinking in Maker Activities (ACTMA): DRL #1543124

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Project website: https://actmaproject.wordpress.com/
2016 Video Showcase: https://vimeo.com/164616853
2017 Video Showcase: https://vimeo.com/214891748
2018 Video Showcase: https://vimeo.com/266546300
https://twitter.com/ActmaProject

ACTMA developed a unit of 15 maker activities and corresponding assessments, which integrate physics, engineering, and computational thinking (CT). These activities and assessments can be used in both formal and informal makerspace learning environments. The activities included electrical circuits, electromagnets, motors, e-textiles, Makey Makeys, and Arduinos. School teachers and informal educators implemented these activities with high school students from under-resourced communities in Chicago in both formal classrooms and out-of-school summer programs. To examine the effect of the activities and assessment as well as improve the activities and assessments, we collected data in multiple ways: pre- and post-achievement tests measuring physics and engineering knowledge as well as computational thinking; attitude surveys; field notes; video, audio, and screen recordings; student notebooks; student focus groups and interviews; and photographs and video of student artifacts.

Some of our major findings and/or products:

- Students who were engaged in maker activities in our summer academies significantly improved their physics/engineering knowledge, CT skills, and CT related propositions.
- We identified four key approaches to informal formative assessment in a making environment that held promise for developing CT skills and dispositions: (a) using materials in conjunction with the promotion of CT concepts and dispositions that strengthen CT, (b) focus on drawing for understanding, (c) the practice of debugging, and (d) fluidity of roles.
- We found that the assessment of CT as a combination of think--aloud and written prompts would activate students' CT--related thinking and make their CT skills explicit and measurable.
- We developed a summative assessment on Arduinos which measures student integration and transferability of skills for CT in physics activities.

Assimilating Computational and Mathematical Thinking into Earth and Environmental Science

(NSF Grant # 1742125)

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Project Website and Virtual Classroom: https://acmes.online/login
NSF Showcase video: https://stemforall2018.videohall.com/presentations/1134

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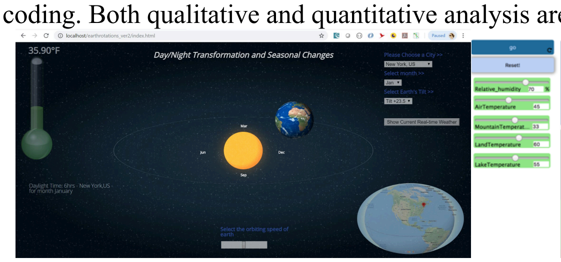
- Livingston Public School District, Livingston, NJ
- Paterson Public School District, Paterson, NJ
- Network for Educational Renewal, Center of Pedagogy, Montclair, NJ
- Center for Research and Evaluation on Education and Human Services (CREEHS), Montclair, NJ
- Clean Energy and Sustainability Analytics Center, Montclair, NJ

Goals/Objectives of ACMES Project:

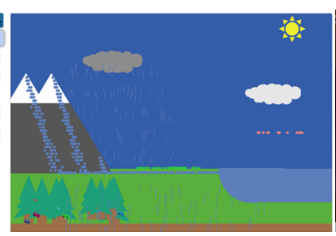
- Design, engineer, and refine instructional modules that integrate computational and mathematical thinking into earth and environmental science education.
- Study the instructional modules with Grade 5-7 students to monitor effects on student learning and to document changes in student reasoning about earth and environmental science.
- Develop and conduct teacher professional development that supports integration of computational and mathematical thinking into earth and environmental science education.
- Investigate teachers' experiences and perceptions of integrating computational thinking into instruction in order to learn how to support teachers in engaging in these instructional practices.

Description of Project:

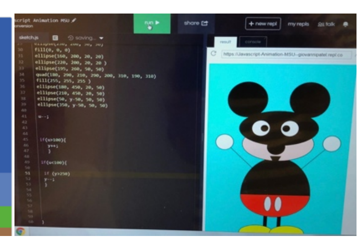
Earth and Environmental Science consists of a variety of complex phenomena and relationships between these phenomena. Computational science, such as mathematical modeling, dynamic parameterized simulation, data generation and analysis as well as scientific visualization, can assist in modeling these complex earth and environmental phenomena and concepts. We consider computational thinking to be the tool that can help students translate their novel ideas in earth and environmental science into action by engaging in logical reasoning, critical thinking and problem solving. We design and develop 10 science modules (Gravity, Orbit, Day night and Seasons, Lunar phases, Water cycle, Rock cycle, Weather, Climate and Greenhouse Effect) aligned with Next Generation Science Standard (NGSS) supported with computer simulations/ written in NetLogo and JavaScript. Two programming modules namely, JavaScript animation and Python are developed for technology teachers to teach coding. Both qualitative and quantitative analysis are conducted.



Day Night Season Simulation



Water Cycle Simulation



JavaScript Student Work

Some Results and Collaboration Opportunities:

We have been working with 30 Science, Math and Technology teachers from four New Jersey suburban school districts and reached around 2,000 students. The assessment analysis for students who took lessons using some of our interactive simulation-based lessons show significantly better improvement including graph interpretation capability than students who took traditional textbook-based lessons. Our STEM interest surveys also show that male students show higher interests in pursuing Engineering and Computer Science related jobs. There are no significant gender difference for interests towards disciplines such as Earth and Environmental Science, Biology and Medicine Science. We welcome any collaborative opportunities on formal and informal learning with local New Jersey schools.

BRIGHT-CS: Building Student Retention through Individuated Guided coHort Training in Computer Science

Award # 1752436

Principal Investigator: Ryoko Yamaguchi
Institution: University of North Carolina Greensboro
Contact email: ryamaguchi@uncg.edu
Co-Principal Investigators: Jamika D. Burge, Thurgood Marshall College Fund; Jim Egenrieder, Virginia Polytechnic Institute and State University

Project Overview

Unlike one-off experiences with little long-term impact, BRIGHT-CS features weekly afterschool programming and a two-week summer camp, with curriculum designed for cultural empowerment and leadership while teaching computer science. Instructors, near-peers (e.g., high school students), and CS professionals serving as mentors are all Black women and women of color in computing. The program is being piloted in four middle schools (two in Arlington Public Schools, VA, and two in New York City Public Schools, NY).

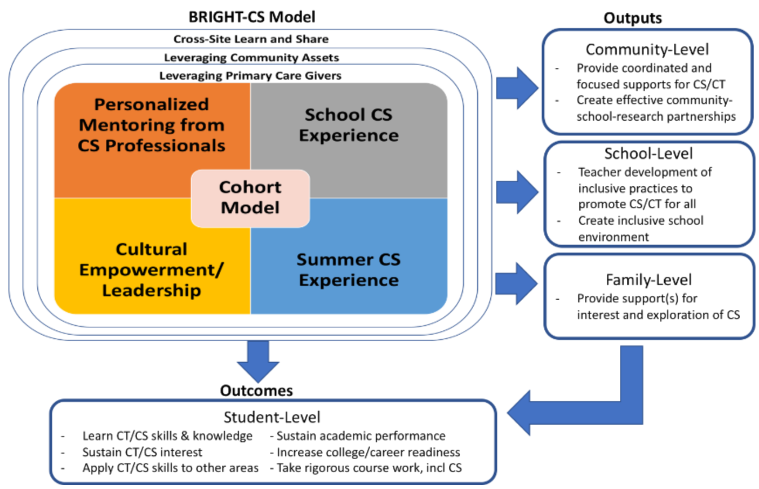


Figure 1: BRIGHT-CS Conceptual Model

Goals

BRIGHT-CS has two main goals: (1) *Create a CS learning ecosystem* that uses a cohort model of positive peers with curriculum focused on empowerment and leadership development, comprehensive computer science and computational thinking experiences, and partnerships with schools, colleges/universities, and non-profit and community organizations; and (2) *Research the effectiveness of this learning ecosystem* to promote the field of computer science and determine best practices for broadening participation to marginalized and underrepresented student groups.

Research Overview

The research is a multi-method implementation study, with a focus on continuous improvement of the program, and student outcomes. The guiding research question for the study is: What are the features of an effective CS learning ecosystem to promote and support interest in CS among middle school girls of color? Quantitative data includes student surveys of computing attitudes and interest, program attendance, and school administrative data. The purpose of the quantitative data is to provide descriptive baseline information about the students. Qualitative data includes student interviews, student observations and think aloud protocols, instructor and mentor interviews, and parent interviews. The purpose of the qualitative data is to understand how Black girls and other girls of color engage in and learn computational thinking (CT) and computer science (CS) skills and knowledge, sustain interest, and apply CT/CS skills in other areas of interest.

Evidence

The interim results of the first four months, with 46 students from four urban middle schools, showed that the participating girls were very interested (37%) and very confident (72%) in learning CS. Students reported greater feelings of commitment to pursuing coursework or careers in CS or STEM. Many students also reported increased technical skills in coding, but they appear to continue to have limited understanding of what computer science is beyond coding. Besides coding skills, one of the other most commonly reported outcomes of the program was increased relationships with other girls in the program.

Broadening Participation of Elementary School Teachers and Students in Computer Science through STEM Integration and Statewide Collaboration

PI: Joyce Malyn-Smith, Education Development Center
Co-PI: Anne DeMallie, Massachusetts Department of Elementary and Secondary Education
Website: https://sites.google.com/site/stemcwithct/home
Contact Email: jmalynsmith@edc.org
NSF Award #: 1543136

Project Goals:

- Design, develop, and pilot modules that integrate computational thinking (CT) into curriculum in grades 1–6, and overlay activities for lessons commonly used in those grades.
- Build the capacity of Massachusetts elementary school teachers to integrate CT into strong math and science lessons.
- Integrate this work into DESE's statewide educational infrastructure for standards and curriculum development and scale-up.

Modules Created:

Grade 1: Money Machines
Light and Shadows
Grade 2: Measuring and Graphing
Effects of Wind and Water
Grade 3: Fractions
Build It, Fix It; Populations and Habitat
Grade 4: Electrical Circuits; Weathering and Erosion
Grade 5: Number Fluency and Fractions
Plants Make Their Own Food
Grade 6: Statistics

Statistics:

- **Grade span:** 1–6
- **Disciplinary areas:** Science and Mathematics
- **Students served 2015–2019:** 1,000
- **No. of participating educators:** 64
- **No. of participating school districts:** 16
- **Digital literacy/computer science ambassadors supporting CT integration statewide:** 10
- **Instructional support videos:** 7

Research Questions:

- Coming into the project, what do teachers know and understand about CT? How does this understanding change after working with the I-Mod(s)?
- What are the strengths of the I-Mods for promoting students' disciplinary learning and their CT?
- How helpful were the supports we provided for your implementation? What additional supports would help you further?

EDC Education Development Center

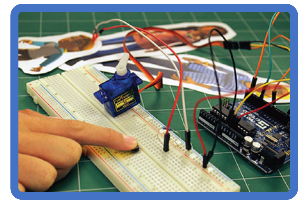
Massachusetts Department of ELEMENTARY & SECONDARY EDUCATION

NSF

Showcase Videos:
2019 video: https://stemforall2019.videohall.com/presentations/1351
2017 video: http://stemforall2017.videohall.com/presentations/993?panel=mc#posts_14993

INFUSECS

Building a Computational Thinking Foundation in Upper Elementary Science with Narrative-Centered Maker Environments



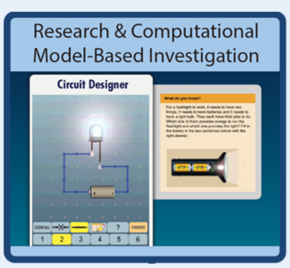
Principal Investigators
Bradford Mott (North Carolina State University), bwmott@ncsu.edu — DRL-1921495
Cathy Ringstaff (WestEd), cringst@wested.org — DRL-1921503

The **INFUSECS** project will investigate how problem-based learning and computational thinking can be integrated with maker-based digital storytelling to create effective and engaging learning experiences in physical science. The project centers on the design, development, iterative refinement, and investigation of an innovative narrative-centered maker environment that supports computationally-rich science learning for upper elementary students. INFUSECS will enable students to collaboratively investigate physical science problems through the creation of interactive science narratives featuring disciplinary core ideas in science, while engaging students in computational thinking practices and supporting them as critical thinkers and creative problem solvers.

Computational Thinking

INFUSECS will develop computationally-rich problem-based learning scenarios that integrate computational modeling, block-based programming, and digital storytelling.

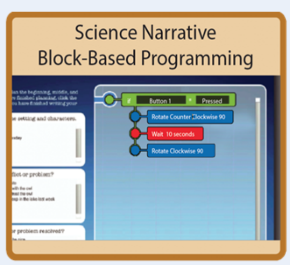
The project will develop a deeper understanding of the challenges elementary students and teachers face with computational thinking in physical science.



Physical Sciences

INFUSECS will engage students in collaborative problem-based learning centered around disciplinary core ideas in science, including energy and matter.

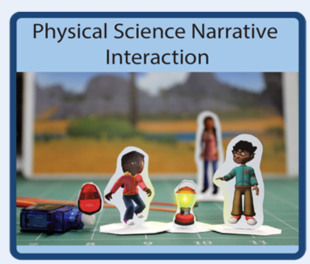
INFUSECS will present students with engaging problem scenarios, while supporting identifying relevant facts, posing hypotheses, researching knowledge gaps, and conducting computational model-based scientific investigations.



Maker-Based Digital Storytelling

INFUSECS will directly leverage programming with fabrication to promote students' reflecting upon their computationally-rich physical science learning experiences.

The INFUSECS maker toolkit will enable students to communicate the findings from their science investigations through presenting the physical manifestations of their science narratives.



Current Activities: The project's initial focus is on gathering input from teachers and students in California and North Carolina to inform the design of the problem-based learning scenarios for INFUSECS, developing an initial version of the INFUSECS narrative-centered maker environment, and developing an understanding of the specific needs of our partner teachers to support their implementation of computationally-rich problem-based learning in their classrooms.

Co-Principal Investigators
Aleata Hubbard (WestEd)
James Minogue (North Carolina State University)
Kevin Oliver (North Carolina State University)

NC STATE UNIVERSITY

WestEd

NSF

Building Educational Bridges between Computer Science and Biology through Transdisciplinary Teamwork and Modular Curriculum Design

STEM+C Award 1742446

Elizabeth F. Ryder (PI), Biology & Biotechnology
Carolina Ruiz (co-PI), Computer Science
Shari Weaver (co-PI), STEM Education Center
Worcester Polytechnic Institute, Worcester, MA
Robert Gegear (co-PI), Biology
University of Massachusetts Dartmouth
Email us at biocsbridge@wpi.edu

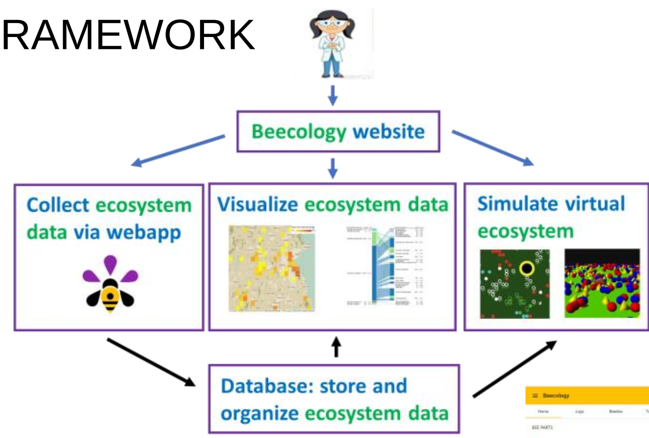
Ronald Cochran, Computer Science
Jenniifer Field, Biology
Nipmuc Regional High School, Upton, MA
Jennifer Hardy, Computer Science
Johanna vanderSpek, Biotechnology
Worcester Technical High School, Worcester, MA

Visit our websites at biocsbridge.wpi.edu and beecology.wpi.edu

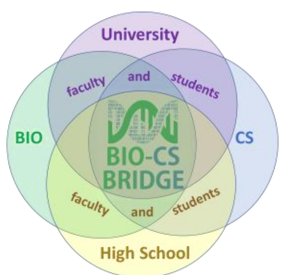
NEED

- Biology students need to learn scientific practices and computational thinking in order to solve complex real-world problems and meet Next Generation Science Standards
- Computer science students need authentic problems to motivate software development and computational thinking skills
- All students are engaged by authentic research about what matters to them
- Difficult for high school teachers to design a curriculum that integrates all of these requirements

FRAMEWORK



APPROACH

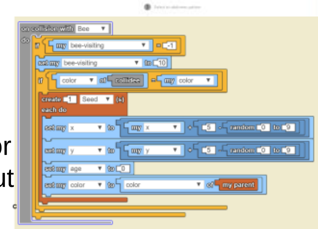


- Build a transdisciplinary team that includes experts in biology, computer science, and education across educational levels from university research faculty and students to high school faculty and students
- Involve students in a Citizen Science Project based on the real-world problem of pollinator decline
- Engage students and teachers in scientific practices using biological data that they collect themselves, and computational tools that they help to design and implement
- Bio-CS Bridge Team designs computational tools; Teacher Leaders develop curriculum, and lead a Summer Institute to train Teacher Integrators in tools and curriculum
- Teachers implement in the classroom and field
- Assessment will be by pre-post attitudinal and content tests, surveys, focus groups
- Approach can be expanded to other STEM fields

MODULARITY

Students can learn to…

- USE computational tools to COLLECT, VISUALIZE, and ANALYZE data
- MODIFY tools; for example, change the webapp to relate to different species
- BUILD tools; for example, design and create simulations or webapps
- TEST HYPOTHESES and make PREDICTIONS about biological systems
- COMMUNICATE information; for example, build a web page about an ecological problem
- Curriculum modules can be tailored to biology or computer science classes and implemented at levels from introductory to AP classes



INITIAL FINDINGS

- Transdisciplinary team process was critical to development of a truly integrated curriculum that fits teachers' needs
- Teacher Leaders report strong student engagement in initial pilot in two schools
- Teacher Integrators will implement curriculum in seven additional schools this year

Building Theories of Scientific Phenomena:

Comparing and Integrating Aggregate Pattern-based and Agent-based Computational Approaches (Award #: 1842375)

Principal Investigator	Uri Wilensky, uri@northwestern.edu
Co-Principal Investigators	Bruce Sherin, bsherin@northwestern.edu
	Hillary Swanson, hillary.swanson@northwestern.edu Northwestern University https://theorybuilding.netlify.com

Project Overview

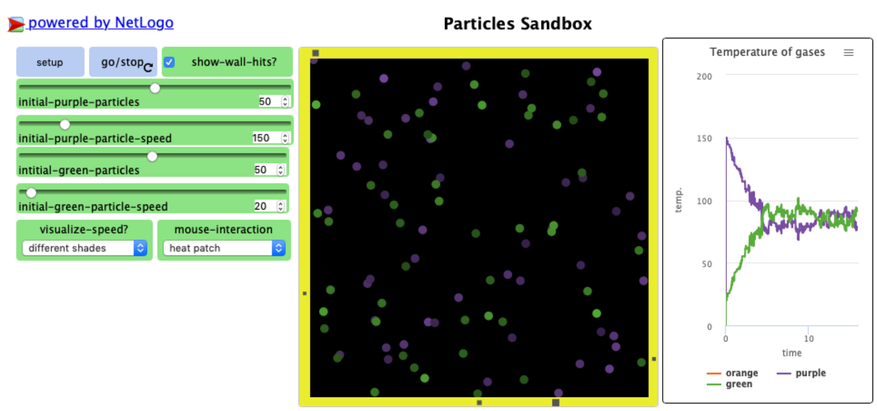
Theory building is a central practice of science. Yet, little curriculum is devoted to helping students learn to build theory. Given the centrality of the practice, we argue it is important to think about how we might integrate theory building into the curriculum. We explore the characteristics and affordances of two approaches to theory building in the science classroom: 1) aggregate-pattern approach, 2) individual-mechanism approach.

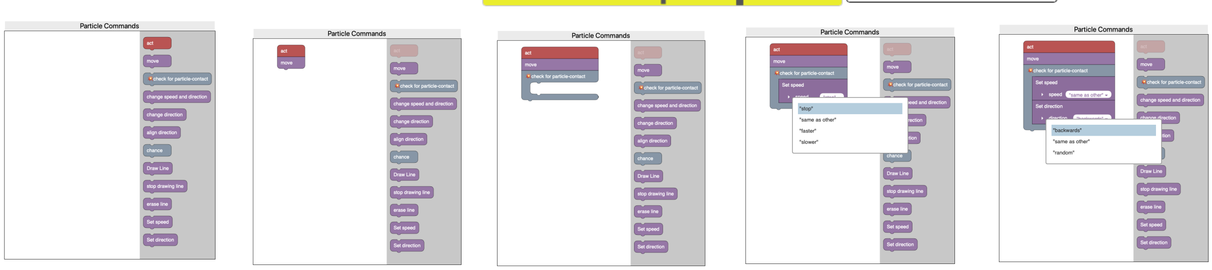
Goals and Objectives

We are interested in understanding how students can engage in "intellectually honest" forms of scientific theory building and how computational tools can be designed to support this. As a part of our research, we are developing tools and materials that middle school students can use to engage in both aggregate-pattern and individual-mechanism approaches to scientific theory building.

Research Overview

Year 1: Design and test tools and materials in a laboratory context; investigate the different affordances of the two theory-building approaches.
Year 2: Refine and test tools and materials in a laboratory context; investigate the different affordances of the two theory-building approaches.
Year 3: Integrate theory-building approaches and test two-week earth and physical science units in middle school science classrooms.





SRI Education™

PRINCIPAL INVESTIGATOR
Andrea Beesley
Andrea.beesley@sri.com
303-755-1786

NSF AWARD NUMBER
1933678

CPR2

Collaborative Research: Collaborative Partnership to Teach Mathematical Reasoning Through Computer Programming

SRI Education is partnering with the University of North Alabama to help middle school mathematics students understand, interpret, and generate algebraic expressions through activites that include Python programming. Working with the programming activities gives students an opportunity to freely "tinker" with mathematical expressions, encouraging them to try multiple approaches without fear of being wrong.

The CPR2 brief theory of action is below:

Inputs	CPR2 Activities	Processes	Short-term Outcomes	Long-term Outcome
Introductory Algebra teachers Introductory Algebra students Computers for Python programming CPR2 PD materials	**PD Activities** Summer institute and follow-up sessions Teachers program and tinker with mathematics Faculty coaching **Classroom Activities** Students • Do programming activities • Generalize mathematical expressions • Make conjectures • Write arguments	**Teacher** Increased comfo rt/proficiency with computer programming as a tool for generalization Ability to teach CPR2 lessons **Student** Increased ability to generalize in mathematics Increased comfort with computer programming as a tool for generalization	**Teacher** Uses programming as a tool in other math lessons Includes computational thinking in other math lessons **Student** Performs better on problems involving generalization Can apply generalization skills to other lessons and contexts	Broader participation of teachers and students in programming, computational thinking

The research questions are:

Phase 1 – Design & Initial Implementation of CPR2 PD (2019-20)

1. To what extent does CPR2 focus on teacher and student needs in learning programming for generalization?
2. To what extent does CPR2 professional development support teachers in learning to use programming as a tool to develop mathematics generalization skills?

Phase 2 – Implementation of CPR2 Activities in Classrooms (2020-21)

3. To what extent are teachers able to implement CPR2 in 7th and 8th grade math classrooms? What are the challenges and what works well?
4. How can teachers support students in their engagement and learning through the designed activities?
5. How can students engage in CPR2 as intended in order to achieve the targeted outcomes?

Phase 3 – Pilot Efficacy Study (2021-22)

6. What effect does CPR2 have on student performance in problems involving generalization?
7. To what extent do students feel more comfortable with programming, and using programming as a tool for math?

CPR2

Collaborative Research: Collaborative Partnership to Teach Mathematical Reasoning Through Computer Programming

Principal Investigator: Dr. Cynthia Stenger, University of North Alabama, clstenger@una.edu

Co-Principal Investigators: Dr. Janet T. Jenkins, UNA, jltruitt@una.edu
Dr. Jessica Stovall, UNA, jstovall@una.edu

Award Number: 1933677

The CPR2 Team at UNA is developing curriculum that incorporates programming to teach abstraction in the 7th and 8th grade math classroom.

CPR2 lessons use computer programming activities to motivate and define general expressions so students learn to reason abstractly. Teachers and school district leaders are involved with the design and implementation of the materials. In Collaborative Research with SRI, the CPR2 Team is currently refining curriculum and assessments and these will be tested in professional learning sessions and then by teachers in their classrooms.

Instructional Model

The CPR2 Instructional Model will help students come to understand, interpret, and even generate general or algebraic expressions.

ESS Identifying the essential characteristics of the math concept

PROG Using Python programming to explore the essential characteristics and, through iteration, find general behaviors.

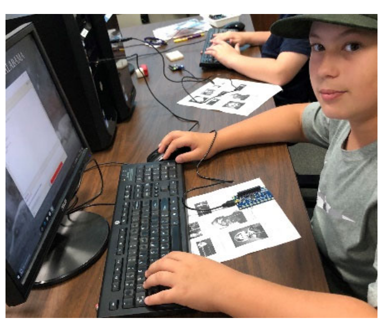
GEN Expressing the general behaviors as abstraction

CA Making conjectures and writing convincing arguments for the conjectures

Summer Institute and Follow-up Sessions

In a two-week summer institute, teachers will be immersed in the four-step model and learn how it builds mental frameworks necessary for generalization.

Teachers will strengthen their classroom implementation through follow-up professional learning sessions with the CPR2 Team during the academic year.



Classroom Implementation

Teachers will implement the model in their classrooms with support from the CPR2 team. Researchers will determine the effects on students in an experimental pilot study.

Impact

The project will facilitate and sustain change in mathematics education at all levels. Ultimately, this will lead to broader participation of teachers and students in programming and computational thinking, especially those currently underrepresented.

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Links to Past NSF Showcase Entries:
https://stemforall2017.videohall.com/presentations/873
https://resourcecenters2015.videohall.com/presentations/548

Computational Sciences Pathway Option for Massachusetts High School Students

Award Number: DRL 1934112
10/2019–9/2022
Reaching All Students!

Project Overview

Imagine high school science courses enriched with opportunities to learn from large data sets and computer models!

This project is developing, testing, and institutionalizing three new courses—Biology+C, Chemistry+C, and Physics+C—to create a new "Science+C" pathway option for students in Massachusetts's 406 high schools.

Core topics for each course are being mapped to the state's recently adopted Digital Literacy and Computer Science Curriculum Framework and to existing +C instructional resources. Additional Science+C curriculum enhancements based on NetLogo are being developed as needed, producing 6–10 Science+C lesson units per course, along with mid and end of unit assessments. These enhancements give students opportunities to dig deeply into science concepts and also develop foundational computer modeling skills to prepare them for work at the Human-Technology frontier.

The Team

PI: Joyce Malyn-Smith
Co-PI: Irene Lee
Co-PI: Anne DeMallie, Massachusetts Department of Elementary and Secondary Education
Institution: Education Development Center
Contact e-mail: jmalynsmith@edc.org

Areas of Focus

Locale: Statewide
Grade span: High school
Disciplinary area: Science+Computing

Research Questions

- To what degree are students enrolled in Science+C courses demonstrating higher levels of computational thinking skills and science knowledge than students who are enrolled in the same course without computational integration?
- Do those enrolled in a Science+C course demonstrate higher achievement on science MCAS assessments than those enrolled in the same course without +C integration?
- In what ways do the results of the above questions vary by previous or concurrent enrollment in a standard computer science course and/or by fidelity of implementation?
- How do teachers describe the impact of the Science+C PD on their teaching?

Massachusetts Department of ELEMENTARY & SECONDARY EDUCATION

NSF

EDC Education Development Center

Computational Thinking Counts in Elementary Grades: Powerful STEM Teaching and Learning for the 21st Century

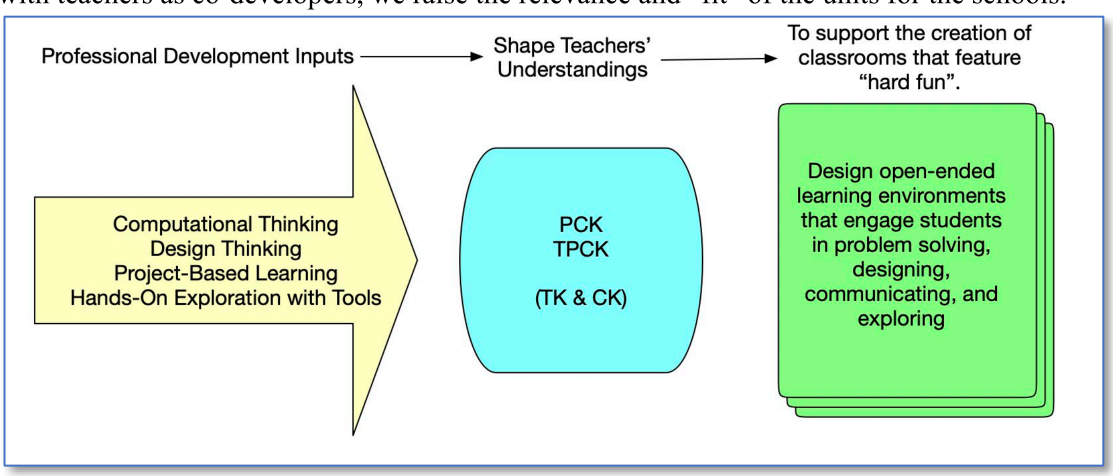
NSF Award: DRL- 1934111
PI: Chandra Orrill - corrill@umassd.edu
CoPIs: Shakhnoza Kayumova & Ramprasad Balasubramanian
http://kaputcenter.org/projects/present-work/computational-thinking-counts/

Overview

We aim to develop a professional development model for bringing computation thinking into mathematics and science curriculum for grades 3-5 in one district. To achieve this, we will implement a three-year professional learning model that includes summer workshops and ongoing support throughout the year. In the summers, participating teachers will learn about design thinking, project-based learning, and computational thinking in addition to being introduced to new technologies. We will offer in-class implementation support and engage teachers in a monthly video club for teachers. Throughout the process, teachers will co-design and implement projects-based lessons and design-thinking projects that they have designed to integrate computational thinking into math and science.

Research

The research will focus on the professional learning model in which teachers will be creating project-based units that incorporate computational thinking into math and science. Given the research at the elementary level, and studies in language, culture and linguistics, we argue that it is important to engage children in computational thinking and disciplinary content and practices early in their academics through project-based and design-thinking projects and activities. Until now, most computational thinking projects have been limited to informal learning environments because of constraints teachers face. By working with teachers as co-developers, we raise the relevance and "fit" of the units for the schools.



The outcomes of this research effort will include: teacher-developed project-based or design thinking lessons; a longitudinal study of teacher professional development for promoting computational thinking in the STEM disciplines in elementary grades; a refined and scalable model for professional development; and a set of video teaching cases that provide teachers with models of implementation of such units in their own classrooms that highlight ways to recognize a wide variety of student thinking strategies, particularly when student thinking is not verbal. We will also develop an annual conference at which teachers from across the district can learn from each other and can share their own experiences.

THE UNIVERSITY OF RHODE ISLAND

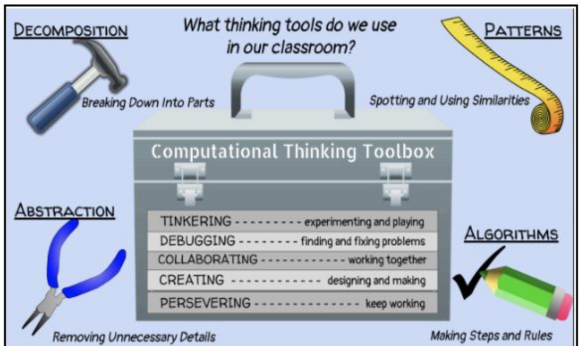
Computing in Elementary School:
An Exploration of Computational Thinking Approaches and Concepts Across Disciplines (1813224)

Name of PI: Sara Sweetman
Institution: University of Rhode Island
Contact Email: sara_sweetman@uri.edu 401-874-6008

Project Overview: This is an exploratory study to better understand the current landscape of how K-5 elementary teachers engage students in the skills and concepts associated with computing, so that future implementation efforts are viable and improve teaching and learning in all disciplines.

Goals:

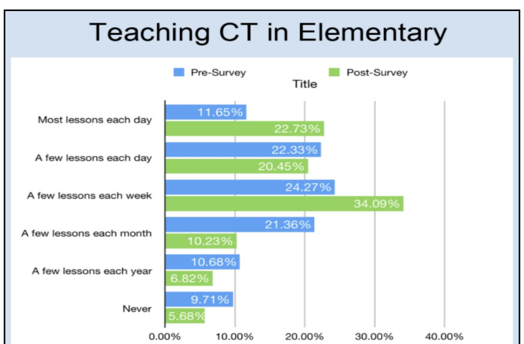
- Increase awareness of computational thinking (CT) for elementary teachers.
- Inform the education community on professional development needs for teachers.
- Develop relationships to build a research-practice partnership (RPP) focused on continuous improvement of STEM+C in elementary schools.
- Share findings with a diverse population of researchers, practitioners, and policy makers supporting advocacy for computing education in elementary school built on best practices in STEM education.



DBIR team designed and distributed educative posters for the elementary classroom

Research Overview:

One of the best ways to get children motivated in developing 21st century skills is to engage them in authentic activities that develop computational thinking skills at an early age. However, policy makers need to consider how to best implement these skills at the beginning of schooling. Researchers cannot assume that elementary school teachers will be receptive to adding CT into their tightly packed schedule, especially since it is an approach many of them were not taught in their formal education. Implementation of CT at the elementary level needs to be thoughtful and done with the needs of teachers in mind for engagement to be effective. Using an exploratory survey design we are looking at the current frequency of computational thinking concepts and approaches in K-5 classrooms. By better understanding how CT concepts and approaches integrate authentically into math, science and other subjects, policymakers and district leaders can be more intentional in supporting both teachers and students to develop an understanding of core computing skills that will provide a strong foundation for further computer science applications.



Teachers grew more confident that CT approaches and concepts were taught in their curriculum after they read definitions and examples in the survey

Team:

Dr. Sara Sweetman, **PI**, University of Rhode Island. Education
Dr. Victor Fay-Wolfe, Co-PI, University of Rhode Island. Computer Science
Dr. Jay Fogleman, **Co-PI**, University of Rhode Island. Education
Dr. Chip McGair, STEM Director. South Kingstown School District.
Jennifer Pietros, PhD Graduate Assistant

Computing with R for Mathematical Modeling (CodeR4MATH)

NSF Award
DRL-1742083

Principal Investigators
Jie Chao, PI
Benjamin Galluzzo, Co-PI
Eric Simoneau, Co-PI

Institution
Concord Consortium
Clarkson University
33Sigma Learning Labs

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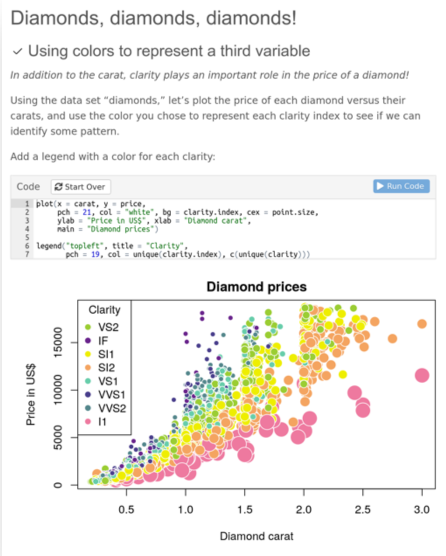
@ClarksonUniv

Importance



Integrating mathematics learning with computing holds potential for success. Yet significant barriers still prevent broad integration of these complex topics into math classrooms. Mathematics and computing are both highly complex and challenging domains on their own, and developing expertise in either is not easy. Combining the two successfully is more complex than simply providing joint resources. Instruction around such integration needs to juggle students' cognitive load and sequence their learning. Any environment proposing to support integrated learning of these topics must leverage visual, dynamic representations to support mathematical conceptual development while providing extensive supports for novice programmers. We will develop code-editing, console-based control, coding history, interactive representations of mathematical outputs; scaffolding students during learning process; and integrating all of it together via a sequenced instructional approach that teachers can implement easily.

Computing with R for Mathematical Modeling (or CodeR4MATH) will provide a robust path for integrating math and computing learning. We will support students in integrated learning of the complex domains of math and computing, employing a coupled learning path that interweaves the two disciplines to generate mutual reinforcement. Leveraging R's open-source ecosystem, we will develop and deploy a learning platform integrating R computing resources, curriculum materials, automated assessment and tutoring, and teacher professional development resources.

Research

Using a design-based research method, we will conduct research on student learning, including:

1. The development of students' computational thinking and mathematical modeling competencies through the CodeR4MATH curriculum modules

2. How different variations of the coupled learning path impact student learning processes and learning outcomes

3. Conditions that moderate the effectiveness of the curriculum modules

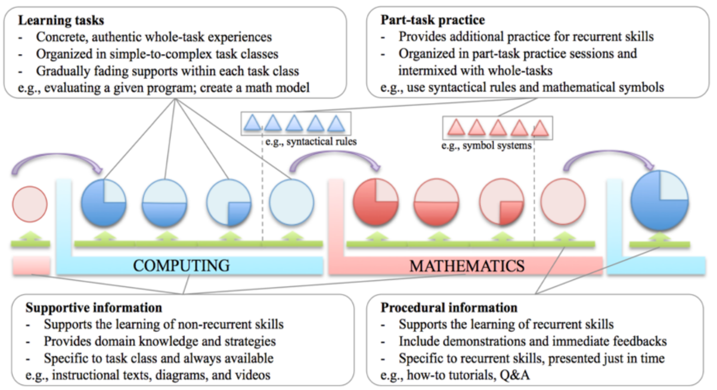


Figure 3. A coupled learning path for computational thinking and mathematical modeling. The blue and red circles indicate whole tasks focused on computing and mathematics, respectively. The size of circles indicates the complexity of the tasks. The shaded area inside the circles shows the amount of learning support provided to the students. The small triangles represent part-task practices.

Collaborative Research: Conference on Integrating Computational Thinking with K-12 STEM Education

DRL 1812860
Robert C. Hilborn, PI
American Association of Physics Teachers
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Project Team: Rebecca Vieyra (University of Maryland), Colleen Megowan-Romanowicz (American Modeling Teachers Association), Marcus D. Caballero (Michigan State University)

This one-year, learning strand, conference-type DRK-12 proposal supported a three-day conference *Advancing the Integration of Interdisciplinary Computational Thinking in the Physical and Life Sciences,* held May 2-5, 2019 in College Park, MD. The Conference was attended by 40 STEM+C educators and STEM+C education researchers involved in integrating computational thinking into K-12 STEM Education and its connection with college and career readiness. The goal of the conference was to develop a set of open research questions whose answers will provide evidence for the effectiveness of computational thinking integration and to articulate the common features of the computational thinking skills and competencies compiled by the computer science community and by the STEM+C education community.

The conference participants identified similarities and differences among the many definitions of computational thinking and formulated a series of education research questions focusing on scaffolding computational thinking development in students, professional development for their teachers and faculty members, and assessing the effectiveness of various strategies in enhancing students' skills in computational thinking. The research questions also address how computational thinking enhances students' understanding of the STEM disciplines. Other topics included the vertical alignment of curricula that integrate computational thinking, appropriate learning progressions, standards, and assessment of the effectiveness of the curricula in fostering computational thinking and deepening the understanding of STEM content. The participants also discussed how to develop a STEM+C education culture that fosters the pervasive implementation of computational thinking.

The participants examined existing frameworks for computational thinking as articulated by elements of the 2012 *Framework for K-12 Science Education* and the 2017 *CSK12 Framework* at the secondary level, similar frameworks at the higher education level, and the early results of education research into integrated computational thinking in several NSF-funded projects. The report from this conference (available in late fall, 2019) will include an analysis of alignment of content, skills, assessment and research metrics to enhance the existing projects, as well as the set of open research questions that will guide funding programs and computational thinking education research efforts. There is an important need to understand teacher professional development and student learning in those courses.

The report will include guidelines and recommendations for integrating computational thinking into secondary and higher education, potentially affecting millions of students across the nation. The recommendations should provide models for integrating computational thinking in all of the STEM disciplines and indeed for many other disciplines as well. The focus on integrating computational thinking into existing STEM courses addresses important practical issues in fostering computational thinking for all: the lack of time in already over-crowded STEM curricula, the lack of adequately prepared computer science teachers, and the lack of funds available to hire computer science teachers particularly in underserved K-12 schools. Short-term impacts will include more coherent and aligned research strategies and assessments for teacher/student learning and teacher efficacy. The long-term impacts of the project's report are likely to include a shift in K-12 attitudes about the need for changes in STEM curricula and STEM teaching, as well as increased pervasiveness and coherence in integrating computational thinking into STEM courses.

Cultivating Creativity to Integrate Computation and Science Problem Solving in Informal Learning

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Award #: 1934087
9/1/19-8/31/21, $530K

Motivation

This project emerges from the increasingly fundamental role computer science is playing in the natural sciences. Computational Thinking (CT) and advanced technologies are now routine for modern scientists, engineers, mathematicians, and agricultural professionals.

Approach

By leveraging *Minecraft*, we hope to present children (5th-9th grade) with engaging problems inspired by real-world challenges that require both an understanding of science and application of CT skills. Creative solutions will be encouraged in several different informal contexts (afterschool, summer camps).

Research Objectives

1. Identify under what conditions Minecraft can be used as an integrated science and CT learning environment.
2. Investigate to what extent challenging scientific scenarios promote creativity in scientific problem solving. Does the ability to code empower learners to behave in more creative ways?
3. Determine whether challenging scientific scenarios act as a trigger for interest in STEM. What specific aspects of STEM are triggered? How are they revealed by observable learning behaviors, gameplay, and talk?

Research Sites

ILLINOIS | College of Education
https://education.illinois.edu/

CU Community Fab Lab
http://cucfablab.org/

WESTERN CENTER ACADEMY MAMMOTHS
https://www.westerncenteracademy.com/

Integration of CT and STEM Learning

MINECRAFT	K12CS PRACTICES/CONCEPTS	PROGRESSION	NGSS SCIENCE TOPICS
Orientation: controls, modes, terrain, biomes, life, resources, +	Core Practices: ‣ inclusive culture (**C1**) ‣ recognize / define (**C2**) ‣ collaborating (**C3**)	Minecraft 101	Science/Eng practices: ‣ observe / analyze ‣ predict / explain ‣ evaluate ‣ communicate
Direct interaction: movement, mining, crafting, building, redstone, +	Problem understanding, sequential execution (**P3.1, P3.2, P4.1**)	→ **Intuitive problem solving**	**MS-PS2 & LS2** ‣ motion & stability ‣ forces & gravity ‣ energy ‣ organisms (plants, animals, microbes) ‣ soil & atmospheric composition
ComputerCraft: CraftOS, turtles, editing worlds, automated actions	**Basics:** variables, loops, conditionals, calculations, (**P5.1-3, P6.1-3**)	→ **Algorithmic problem solving**	
Complex Interactions: customization, bot/player coordination, control of environments	**Functions**: define functions, refactor/reuse code, documentation (**P4.1, P4.3, P4.5**)	→ **Abstraction & Modeling**	**ESS1,2 + crosscutting** ‣ rainfall / moisture ‣ temperature ‣ explanations ‣ scientific method

Our learning progression aligns CT development with Minecraft activities. Learners solve scientific problems

Students write LUA code in game using ComputerCraft

Programmable turtles for various tasks

CAPACiTY

CULTURALLY AUTHENTIC PRACTICE TO
ADVANCE COMPUTATIONAL THINKING IN YOUTH

Georgia Tech | Center for Education Integrating Science, Mathematics & Computing

Project Team

PI: Marion Usselman
Co-PI: Meltem Alemdar
Co-PI: Douglas Edwards

Senior Personnel

Diley Hernandez
Michael Ryan
Michael Helms
Sunni Newton

NSF Grant #1639946
URL: https://ceismc.gatech.edu/capacity

Project Overview: CAPACiTY has created, piloted and is assessing the impact of a new curriculum for the Georgia high school **Introduction to Digital Technology (IDT)** course, which is the first course in the IT pathway within Georgia's Career and Technical Education program. This new curriculum is grounded in project-based learning, computational thinking, and cultural-relevance pedagogy, and integrates the NGSS cross-cutting concepts of Patterns and Structure & Function. In the course students select a problem relevant to them as teenagers and work collaboratively to identify solutions to the problem. To learn computational skills, they design and construct four digital artifacts: (1) a narrated PowerPoint presentation about their topic, (2) a website using Google Sites, (3) coded music in Python using EarSketch, and (4) an app-based game using App Inventor.
The CAPACiTY curriculum targets 15 concepts from the revised CSTA standards.

Culturally Authentic Practices (CAPs): An essential component of the CAPACiTY curriculum is the integration of culturally authentic practices (CAPs), designed to promote students' voice, choice, and belonging in the classroom. These pedagogical practices, embedded throughout the curriculum, are grounded in motivational theories like self-determination and are designed to help decrease the effects of social identity threat that students from underrepresented groups might experience in CS-related fields. The project-based learning nature of the curriculum supports CAPs by allowing students to select their own problem to work on. Students in CAPACiTY have chosen to tackle a variety of problems, including sleep deprivation, college debt, obesity, and police brutality. By learning how to use their computer science skills to raise awareness about issues they care about, students can experience a sense of agency within the context of their classroom.

Research: CAPACiTY is analyzing the feasibility and effectiveness of teaching computational thinking and programming using project-based learning and NGSS cross-cutting concepts. The research focuses on determining the impact of the CAPACiTY course on student perceptions of computing, and how the course affects student engagement, motivation, content understanding, and persistence in computer science. Additionally, the research is exploring how the embedded CAPs activities affect student engagement and interest. The research uses a variety of methods, including interviews, focus groups, surveys, knowledge assessments, analysis of classroom video, classroom observations and field notes.

Results: Preliminary results show that teachers successfully incorporate culturally authentic and PBL-based practices into their teaching, and that the course has positive impacts on students' cognitive engagement and their intention to persist in computer science.

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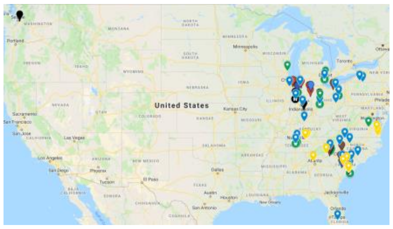
NSF STEM For All Video Showcase:
2018 https://bit.ly/30HNHwr
2019 https://bit.ly/2HtirKc

Curriculum and Assessment Design to Study the Development of Motivation and Computational Thinking for Middle School Students across Three Learning Contexts

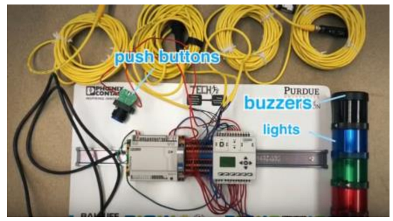
NSF Award DRL#1640178



Students invent physical exergame systems to get groups moving and learn Scratch programming, flowchart programming, and wiring electronic components to an industrial-quality microcontroller to build their inventions. The final projects by two different school teams are illustrated on the left and right as each team demonstrates their exergames in action.

Middle school teachers complete a 6-day academic summer boot camp to learn the 30-hour TECHFIT curriculum that they will teach either as a class or as an afterschool program during the school year. The curriculum was developed under NSF Award DRL#1312215. Counting both NSF awards, as of August 2019, eleven sets of teacher PDs have been offered to over 170 teachers from over 70 schools in twelve states (see map on the left).

Each school team receives a technology toolkit currently valued at $4700. See picture to the right for a basic wired system using toolkit components.



Research objectives: 1) Examine self-reported motivational, affective and cognitive outcomes of teachers and students to determine impact based on implementation context (class or afterschool program). 2) Understand what levers and barriers exist that can catalyze or impede the integration of out-of-school curricula focusing on technology and CT into in-school contexts; identify how middle school teachers from varied disciplines integrate a technology curriculum into their discipline, school and classroom context; understand what role (if any) their understanding of computational thinking plays in their practice.

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From 2018 survey data collected from 739 students:

Current study preliminary results: When perceptions of teacher behavior and psychological assets are similar, the role of learning context (in-school versus afterschool) is similar; however, delivery context still influenced student motivation for participation.

For more information about this project, visit the website at https://techfit.tech.purdue.edu/ or watch the video submission by the project team for 2018 NSF Showcase: https://www.youtube.com/watch?v=MHhE_7PafPc.

DRL 1742140

Debugging by Design

Developing a Tool Set for Learning and Teaching Debugging with Electronic Textiles to Promote Computational and Engineering Thinking in High School

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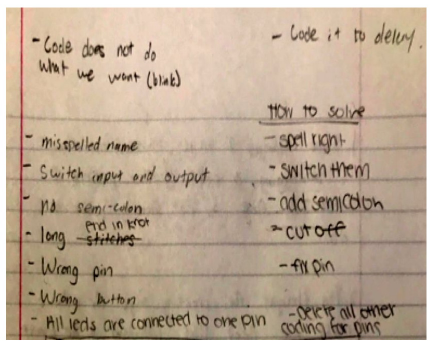
While much attention has focused on developing tools and activities that support learners in designing fully finished and functional applications such as games, robots, or e-textiles, far less attention has been given to students learning to identify and fix problems in the applications they make. We help students and teachers learn troubleshooting and debugging—the ability to find and fix problems in program code and circuit as they make electronic textiles. Electronic textiles include sewable microcontrollers, sensors, and actuators and integrate engineering with computing. We are researching and developing tools and activities for the electronic textile unit in *Exploring Computer Science* (ECS), an introductory computer science course for high school students. In one of our approaches students and teachers **design** bugs in code and circuits for learning—or what we call *debugging by design*—to help them better understand and become more competent in identifying and solving problems.



DEBUGGING ACTIVITIES
What activities help students learn to debug code and circuits?

The images to the left show a buggy electronic textile project designed by a high school student and the list of bugs he included.

DEBUGGING TOOLS
What tools help students debug code and circuits?

The image to the left shows a 'low floor multimeter' hand-tool. With it, students can better understand what is happening inside their circuit and for educators to visualize and explain abstract concepts. The device will display sensor values, voltage, and continuity in a circuit.

In the coming year we will work with several *Exploring Computer Science* classrooms in which teachers and their high school students will be using debugging by design tools and activities as part of the electronic textile unit. The ECS electronic textile curriculum unit can be found at **www.exploringcs.org/e-textiles** All debugging classroom activities and tools will also be published at this site.

Decoding Urban Ecosystems:
Computational Thinking Integration
in Middle School STEM
(NSF Grant # 1934039)

Project Team:
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In this three-year research project, we will design, implement, and study a program that engages 125 New York City (NYC) middle school students in a new three-week computational thinking (CT)-integrated science curriculum. Students will simultaneously engage with ecosystem dynamics and use CT practices in the context of computer modeling and simulations. The project's research will focus on identifying innovative ways of supporting students to learn about and actively engage in authentic science practices through integrating CT into curriculum.

The overarching **goals** of this project are:

1. To develop, implement, and study a CT-integrated science curriculum for middle school students that measures the impact of CT on students' understanding of ecosystems as complex systems and self-efficacy with CT practices.
2. To recommend a pathway for broader impact that aligns to NYCDOE implementation of CT professional learning for middle school science teachers.

To meet these goals, the project **objectives** are:

1. Create and implement a curriculum that builds upon promising practices and is responsive to evaluation and research findings.
2. Conduct a research agenda aligned with the needs of the field to fully understand the integration of CT as a foundational approach to cross-disciplinary learning.
3. Engage four NYC teachers as co-researchers to enrich data analysis and inform a set of written recommendations to guide professional learning activities in a Phase 2 of this project.

Guiding our study are the following **research questions:**

1. What is the impact of the intervention on students' learning of CT and ecosystem concepts?
2. What are the connections between CT practices evident in coding/decoding and developing a deeper understanding of scientific processes?
3. What are the affordances of CT practices on developing a deeper understanding of scientific processes?

This research seeks to increase knowledge in STEM and CS education fields by deepening the understanding of how students learn when given supports to make connections between CT in coding and decoding of computer models and scientific processes.

Designing and Exploring a Model for Data Science Learning for Middle School Youth

Award Numbers: DRL-1742255 and DRL-1741989 (collaborative grant)
PIs: Andee Rubin, TERC (andee_rubin@terc.edu) and Jan Mokros, Science Education Solutions (jmokros@scieds.com)
Partners: Gulf of Maine Research Institute, Maine; Program Evaluation Research Group (PERG) at Endicott College, Mass.; Oxford Hills School District, Maine (summer camp program); Malden, Mass. YMCA (summer camp program); Girls Inc., Lynn, Mass. (after-school program)

TERC | Because math and science build futures

SCIEDS SCIENCE EDUCATION SOLUTIONS

Project Overview:

What aspects of data science are accessible to middle school youth, given appropriate technology, datasets, and materials? We are developing and implementing out-of-school data science modules with community partners in urban Massachusetts and rural Maine communities. We target middle school participants from populations under-represented in STEM, including girls, youth of color, economically disadvantaged, and rural youth. Youth participate in 10-hour modules after school or in summer camp. They use the Common Online Data Analysis Platform (CODAP) as a data analysis tool, in conjunction with large, pre-existing datasets and data that they collect themselves. Each module focuses on a high-interest scientific or social science topic, selected with input from youth advisory groups. The project is developing three modules, a survey measure of data science dispositions, and an interview assessment of students' ability to ask and answer questions with data. The project integrates computer science, the mathematics of data, and scientific topics.

Goals for Youth:

- Appreciate the ubiquity of data and the potential for learning from data
- Be aware of the complexities of measurement and look at data through these complexities
- Understand the case/attribute structure of data
- Have experience with describing distributions and distributional shape
- Examine relationships of attributes within a dataset
- Understand how data representations are constructed by mapping attribute values to representational elements, both on the computer and off
- Learn to address questions about data through a series of "data moves" with technology
- Engage with social science and scientific data in ways that are intellectually and personally satisfying

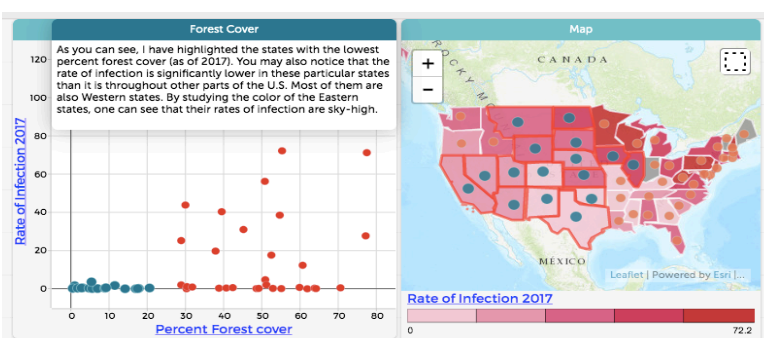

Image: Example of a student's data representation in CODAP from the Ticks and Lyme module. Rate of forest cover is compared to the rate of Lyme in each state. Green dots represent states with a low percentage of forest cover. Red dots represent states with medium to high forest cover.

Accomplishments/Outcomes:

We have developed and implemented two modules, including accompanying data sets, on the topics of: **Teens and Time** (using Pew Research Institute and Census at School datasets) and **Ticks and Lyme Disease** (using CDC and NOAA data sets). A consistent finding from this work is: *youth can develop iterative questions about the datasets and easily use CODAP to investigate their questions, especially about relationships between attributes.*

Designing Biomimetic Robots

(NSF Grant # 1742127)

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Project Overview: In most middle schools, learning is segregated by discipline – science is taught in one class, and engineering or computing are taught in another (if at all). Yet recent trends in science and engineering education suggest this approach is outdated. The Designing Biomimetic Robots project is designed to support middle school students in thinking across three disciplines (biology, engineering, and robotics). In this program, students first study the natural world to learn how animals accomplish different tasks. Then, they engineer a robot that is inspired by what they learned.

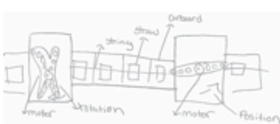
Goals and Objectives: To develop, and study, an interdisciplinary learning opportunity for middle school students that supports the development of engineering and science content and practices, and computational thinking (CT) practices.

Evidence of Student Learning: The diagram below demonstrates how the robot design task integrates student learning in science and engineering while supporting the use of CT practices (highlighted in red).

Curriculum specifies design goal: make a robot that digs

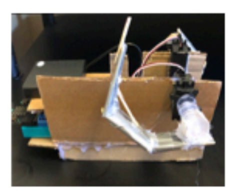
Students identify specific body parts that help the pangolin dig – claws, hands, head, nose – and document how each part (**decomposition**) contributes to the animal's ability to dig effectively.

Students **abstract** pangolin's motion into a 3-step process: extend arm, scoop dirt, pull back. Students identify important parts of pangolin involved in digging (claws, hands, arms) .



The group's initial design closely mimics the structures and functions of the pangolin; focuses on hands and claws that can scoop debris in a way similar to the pangolin. Students **prioritize parts and actions** on the robot that maximize digging motion.

Students **iterate** on design for the pangolin's hand, trying to find a stable design that will still reflect the function of a pangolin hand + claws. Next, students imagine how to translate the scooping motion into robot actions (**algorithmic thinking**).



Front (left) and side view (right) of a the final robot. The robot's claws spin in coordinated circles to dig.

Our research examines the ways in which the design task encourages students to develop models of structure-function (S/F) relationships. We posit that when students are forced to defend their robot design choices, they are given an opportunity to explain and argue for the relationships between animal S/F and robot S/F. Thus, the design task provides an opportunity to describe, discuss, and argue about structure-function relationships in a more complex way than a science or engineering task would alone.

Developing the Next Generation of Problem Solvers:

Investigating the Integration of Computational Thinking (CT) into Preschool Mathematics and Science

DRL #1639850

PI: **Ximena Dominguez** (Digital Promise Global); Co-PIs: **Shuchi Grover** and **Phil Vahey** (SRI Education)
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Our project aims to better understand how various elements of Computational Thinking (CT) align with the abilities and interests of young children and explore how CT can be integrated with mathematics and science learning to achieve mutually supportive learning.

Our work brings together early childhood researchers (**Digital Promise Global** & **SRI Education**), developers (**Curious Media**), expert advisors, preschool teachers and families (**Napa COE**) to engage in exploratory research and co-design. In the first phase of the project the team identified 4 CT skills that resonated with early learning school readiness goals: **(1) problem decomposition; (2) algorithmic thinking; (3) abstraction; and (4) debugging**. One of the main goals was generating a **learning blueprint** that delineated how these CT skills might be addressed and evaluated in preschool. This blueprint was then used to guide the design of **prototype hands-on and digital activities across home and school**. Integration points with mathematics and science were then documented in the blueprint as they emerged organically.

Our team then held four co-design meetings where teachers (n=3), coaches (n=1), parents (n=3), and researchers (n=7) brainstormed and generated activity sketches. The resulting activities were later pilot-tested in two preschool classrooms and three homes. Researchers visited each classroom 6 times and each home up to 3 times. During each visit, a researcher co-enacted the activity along with the teacher/parent and children and another observer recorded a running record/completed an observation protocol.

Data from the pilots were qualitatively coded and evaluated to inform iterations to the activities. Of the activities co-designed, a total of 26 classroom hands on activities, 6 home hands on activities, and 2 digital apps (for use across home and school) were selected as promising. Analyses also revealed the regarding the integration of CT with early mathematics and science:

- *CT & Math:* Activities designed to promote algorithmic thinking organically integrated visual spatial thinking, whereas activities designed to promote problem decomposition organically integrated shapes. Opportunities to practice counting, cardinality, and comparison of quantities were organically integrated across all CT skills.
- *CT & Science:* Activities designed to promote abstraction naturally provided opportunities for children to engage in observation, description and sorting, whereas activities designed to promote problem decomposition naturally provided opportunities for children to engage in prediction, experimentation, and argumentation. A variety of science concepts (e.g., buoyancy, food and animal groups) can also be addressed.

Thoughtful design for a seamless integration of CT in preschoolers' lives is key to developing the next generation of problem solvers. Unlike most current approaches that seek to introduce young children to fundamental ideas of CT through programming and robotics activities, our work addresses the synergistic integration of CT learning with other key early childhood learning domains. By leveraging the power of partnerships with stakeholders we have identified CT skills that align with the abilities and interests of young children and the contexts in which they may be feasibly promoted to support school readiness, especially for underserved populations.

Our next step includes conducting a field study this Fall to examine implementation and the promise of the designed activities across home and school. Stay tuned!

https://digitalpromise.org/initiative/learning-sciences/stemc-prek-developing-next-generation-problem-solvers/

ENGAGE: A Game-based Curricular Strategy for Infusing Computational Thinking into Middle School Science

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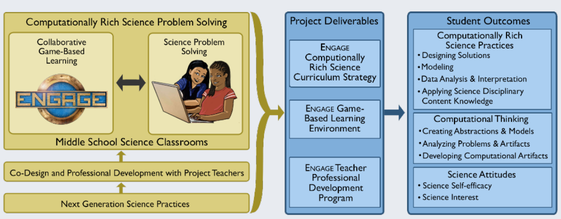
Eric Wiebe (co-PI)
North Carolina State University

Kristy Elizabeth Boyer (co-PI)
David Blackburn (co-PI)
University of Florida

Project Overview

- The ENGAGE team investigates (1) a science curricular strategy that focuses on computational modeling of life science concepts for middle school students, and (2) an immersive game-based learning environment that infuses computational thinking (CT) into middle grades science education.
- ENGAGE provides students with early explorations of standards-based CT and the related practices.
- Students learn about life science topics and develop CT skills throughout multiple weeks of game-based learning and modeling & simulation activities.
- ENGAGE includes an evidence-based teacher professional development program that supports teachers in the integration of CT into middle grade science.



Standards Alignment

- ENGAGE activities are aligned with the K-12 Computer Science Framework and Next Generation Science Standards.
- CT practices from the K-12 Computer Science Framework inform ENGAGE science problem solving.
- ENGAGE offers a game-based learning environment in which students learn about life science topics focused on CT problem solving.

Center for Educational Informatics
www.cei.ncsu.edu
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Current Activities

- The team is preparing for the next iteration of the ENGAGE classroom implementation that will integrate game-based learning and computational modeling activities.
- The team will conduct the final classroom study, which will investigate the impact of both game-based learning and computational modeling activities.

Classroom Implementations

- Students participate in multiple weeks of CT problem solving with the ENGAGE learning environment.
- In Year 3 (2018–2019), 16 middle school teachers implemented the Engage learning environment in 53 classrooms with 1,213 students (954 consenting students) at 9 different schools in North Carolina and Florida. To support classroom implementations of ENGAGE, the teacher professional development training was conducted for 14 teachers in North Carolina, 7 teachers in Florida, and 5 teachers in Texas in Year 3.
- Students interacting with ENGAGE exhibited significant learning gains on the *CS Concepts Inventory* assessment ($p<.001$, Cohen's $d=0.18$) and the *Computational Thinking* assessment ($p=.018$, Cohen's $d=0.20$).

NSF DRL-1640141

EDC Education Development Center

Engaging Preschoolers in Data Collection and Analysis to Promote Computational Thinking: Exploring a Technology-Based Approach

PIs and project leaders: Ashley Lewis-Presser (PI); Jessica Young (co-PI); Paul Goldenberg; Kristen Reed; Deborah Rosenfeld, Janna Kook

Funding period: 10/19-9/22

Education Development Center (EDC)

Contact: alewis@edc.org

Description and Goals

This three-year exploratory project will create and test a set of developmentally appropriate problem-solving activities for preK students (4-5-year-olds) that integrates mathematics and computational thinking (CT) by engaging children in data collection and analysis investigations. Using hands-on materials and a digital tool that collects data and creates visual data displays, the team will target specific math skills that are naturally engaging for young children (e.g., counting and categorizing), and provide a foundation for later mathematics competencies. Ultimately, this project will set the stage for children who are under-represented in STEM to succeed in mathematics and computational thinking tasks in elementary school and beyond.

GOALS:

- To advance knowledge about how to foster preK children's mathematics learning and computational thinking.
- To advance research and development of high-quality instructional resources that integrate early mathematics and computational thinking.
- To leverage diverse perspectives to yield a theory of change explaining how the learning activities and materials lead to the desired learning outcomes.
- To transform current conceptions of young children's computational thinking and related developmental capacities.

Activities and Outcomes

This project addresses the urgent and persistent need to create engaging, high-quality mathematics learning opportunities for young children that promotes computational thinking and mathematics knowledge.

The iterative, design-based approach will produce:

- *Learning Goals and Theoretical Framework*: create and refine a learning blueprint and conjecture map that articulate what children can and should learn and the mechanisms by which they engage in that learning;
- *Preschool Classroom Intervention*: develop a set of 9 hands-on, play-based, real world learning activities with a digital tool that enhances participating students' and teachers' technology fluency.
- *Preschool Assessment*: develop assessments to improve and measure preschoolers' mathematical and computational thinking.

NSF Award DRL-1933698

Exploring Physiological Computing Education in the Alabama Black Belt

DRL 1838815

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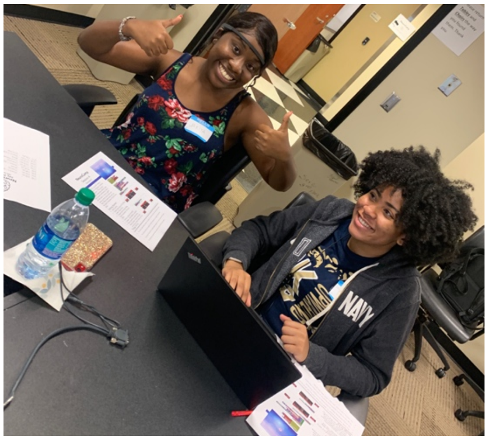


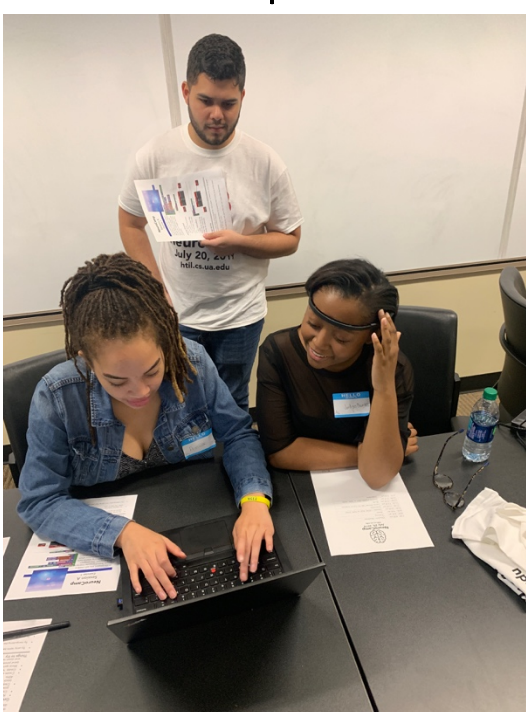
Project Description

Advances in Brain-Computer Interfaces (BCIs) are enabling the exploration of novel input techniques. Innovations in this area have resulted in technologies such as neuroprosthetics and brain-controlled wheelchairs. However, there is a lack of research investigating the design of technological tools that prepare the future workforce for this emerging technology. Furthermore, there have been limited investigations of how K-12 technological tools featuring BCI technology support the acquisition of computational thinking skills. Our project seeks to address this gap by exploring BCI education tools.

Project Goals & Objectives

Our long-term goal is to advance knowledge at the intersection of physiological computing and Computer Science education. The objective of our current project is to develop a tool for K-12 BCI education. We also aim to extend knowledge regarding how our contributed tool influences students' acquisition of computational thinking skills.

Neuro Summer Camp 2019



To assist us in our goal, we recruited 11th and 12th graders from the historic Alabama Black Belt (ABB) region, which consists of a high enrollment of African American students. Sixteen ABB students were invited to a Neuro Summer Camp (NSC) at the University of Alabama. During the summer camp students learned basic concepts related to capturing and processing brain data (e.g., mounting EEG device, filtering EEG data, creating neurofeedback games).

Preliminary Findings

During the summer camp local high school students participated in activities that involved the design of neurofeedback applications using the developed educational tool. Our preliminary analysis determined that students' BCI self-efficacy significantly improved after being exposed to our tool. We are currently in the process of analyzing artifact-based interviews to determine patterns of computational practice and computational perspectives that emerged during NeuroCamp.

Exploring the Integration of Computational Thinking into Preservice Elementary Science Teacher Education, *CT→PSTE*

(Award #1639891)

PRINCIPAL INVESTIGATOR: Diane Jass Ketelhut djk@umd.edu
co-PRINCIPAL INVESTIGATORS: J.Randy McGinnis, Jandelyn Plane
External Evaluator: Troy Sadler

Website: https://go.umd.edu/STEMC http://stemforall2018.videohall.com/presentations/1174

This project addresses the challenge of how to prepare undergraduate elementary preservice science teachers to integrate computational thinking (CT) into their elementary STEM instruction. We have used video, surveys and a broad variety of artifacts to help us understand how teachers conceptualize CT and CT-infused science lessons to help address this project's fundamental question, "*What strategies are most effective in integrating computational thinking into elementary preservice teachers' pedagogical preparation experiences in science in order to cultivate and improve access to CT for all students*?"

Goals and Foundational Theory

With the increased focus on integrating computational thinking within general education subjects and the presence of CT in the Next Generation Science Standards (NGSS), it is essential that pre-service and in-service teachers have CT experiences, and practice integrating it into everyday science lessons. Since CT is relatively new within schools, the first step is to improve the preparation that elementary teachers receive about CT to increase both the frequency and quality of exposure for elementary-aged children to CT. This exposure can then build throughout their schooling. Our project's overall goal is to transform elementary school teacher practice through teacher education and professional development opportunities with the aim of supporting teachers to integrate CT strategically and significantly into science instruction for all young learners. We use theories of Design-based research (DBR), Communities of Practice, and the Interconnected Model of Professional Growth towards our design and analysis.

Activities

This project designed, implemented, and tested

- A CT module within a science methods course to introduce students to CT, and prepare them to integrate it in their science lessons. Drawing upon CT recommendations by the NRC and aligned to the Next Generation Science Standards, this module focused on the practices that comprise CT, how they can advance students' understanding of scientific concepts, and how teachers can integrate these practices into their lesson plans.
- An extracurricular Science Teaching CT Inquiry Group, ($STIG^{CT}$), an extended collaborative learning experience. The purpose of $STIG^{CT}$ was to cultivate a community of practice among designers, and inservice and preservice elementary teachers to create CT-infused elementary science lessons.

Instruction in how to convey to young learners the integral nature of CT for STEM career awareness and readiness was included in both experiences.

Results

As part of our DBR study, we reformulated all aspects of our intervention from years 1-2, using surveys, interviews, and videos to support the redesign. Figure 1 shows the positive impact of that on preservice teachers. Success was higher for those who also did the $STIG^{CT}$.

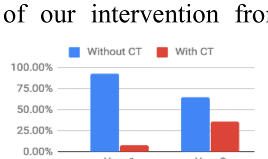


Fig 1. CT Integration in Science Methods Lesson Plans

80% of $STIG^{CT}$ in-service and pre-service teachers successfully integrated CT in their final lesson plans. Teachers most often integrated data practices or computational models in those lesson plans seamlessly.

Our Framework

One of our promised products was a framework to help guide teachers and teacher educators on the use of CT practices in elementary science education. Figure 2 shows our draft framework. We modified existing frameworks, and designed it for elementary school. We have found that CT systems thinking remains problematic.

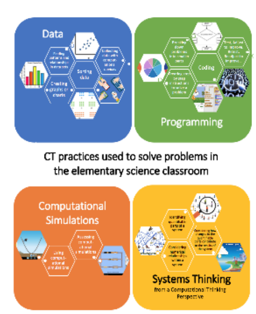


Fig 2. Elementary CT draft framework

Foregrounding Agency vs Structure: Models for Designing Integrated Mathematics and Computational Thinking Curriculum

DRL#1742257

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Project Overview

The project will design and study new learning environments integrating mathematical and computational thinking. Using design-based research as a methodology to support iterative design and research, the project will explore two core tensions that are relevant to the integration of mathematics and computational thinking. Each tension deals with how to balance competing goals, and investigates the influence of foregrounding one goal over another. Specifically, the project will design, test, and begin to apply in schools a set of modules that contrast: 1) foregrounding mathematics vs. computational thinking; and 2) foregrounding agency vs. structure.

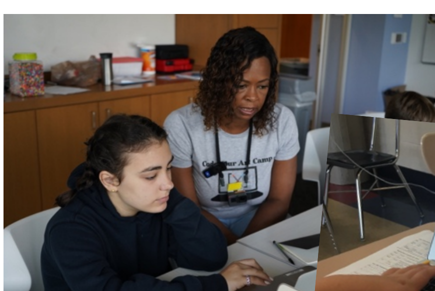
Study Details

The model of implementation includes two summers of camp sessions for middle school students, and a year of implementation in classrooms, thus allowing exploration beyond the potential for math and computational thinking to be integrated, and extending into what such integration looks like in the institutional context of schools.

The research questions investigated include: (1) What are the advantages of modules that teach mathematics through computational thinking (foregrounding mathematics) vs. those that teach computational thinking through mathematics (foregrounding computational thinking)? (2) What are the advantages of modules that teach computational thinking through open exploration (agency) vs. game play (structure)? (3) What kinds of instructional supports do math teachers need or request as they are teaching students at the intersection of computational thinking and mathematics?

Products

The project will result in (a) a set of instructional sequences for middle school that propose productive intersections of computational thinking and mathematics, (b) an understanding of how and why these instructional sequences support diverse participation, and (c) conjectures about the support math teachers need to integrate computational thinking in their classrooms. Different sections for students will be created to compare different conditions that will foreground mathematics, computational thinking, structure or agency.



PFACS Formative Assessment for Computer Science in NYC

NSF grant numbers: 1742011 and 1741956

Nathan Holbert, PI, Teachers College, CU, Holbert@tc.columbia,.edu
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Project Team

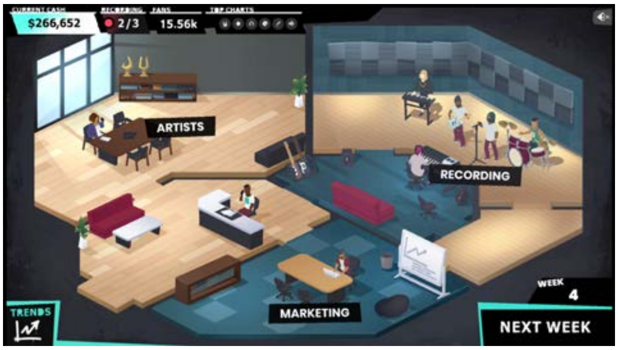
Website: www.beatsempire.org

Overall Project Goal: To address how we can create valid and useful framework-aligned, yet curriculum neutral, formative assessments of students' understandings of Data and Analysis in game-based environments that participants experience as convenient, engaging and meaningful.

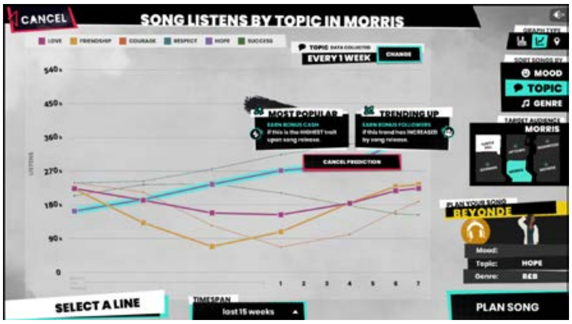
The project developed ***Beats Empire***, a "music manager" role-playing game that provides students with opportunities to engage with data while making decisions in order to produce top-charting songs.

The game measures skills related to the Grade 6-8 Data and Analysis strand of the K-12 CS Framework.

Constructionist games empower learners to encounter domain specific practices and representations through the creation of personally meaningful artifacts (Berland et al, 2014; Holbert & Wilensky, 2018). *In Beats Empire* this constructionist approach is coupled with an evidence-centered assessment design (Mislevy & Haertel, 2006), and a participatory design process (DiSalvo, 2016).



Initial piloting found that students were able to engage with Data and Analysis in a variety of ways, displaying a range of abilities and game play strategies. Students found the game engaging and meaningful.



Next Steps:

- Further development of the teacher dashboard and teacher follow-up activities.
- Additional piloting

Fostering Computational Thinking with Self-Regulated Learning:

Supporting High School Science Student Data Practices

Principal Investigator:	Erin Peters-Burton, George Mason University: Epeters1@gmu.edu
Co-Principal Investigators:	Peter Rich, Brigham Young University: Peter_Rich@byu.edu
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	Anastasia Kitsantas, George Mason University: akitsant@gmu.edu
Software Development:	Phil Winne, Simon Fraser University: winne@sfu.edu
Practitioner Partners:	20 teachers from Loudoun County Public Schools, Virginia
NSF award number:	#1842090

This researcher-practitioner partnership is developing new transdisciplinary approaches to computational STEM teaching and learning that will integrate the fields of Computational Thinking (CT) and Self-Regulated learning (SRL) into science instruction in four content areas: Earth Science, Biology, Chemistry, and Physics.

The project provides professional development for high school teachers that includes instruction on CT, SRL, and on the development of an online Science Practices Innovation Notebook (SPIN). Teachers collaboratively develop lessons that infuse CT & SRL, upload the lessons into SPIN, implement those lessons in their classrooms, and then collaboratively analyze student work captured by SPIN. The research team will employ learning analytics to uncover patterns and develop a CT learning progression for grades 9-12.

Approach

Informed Exploration

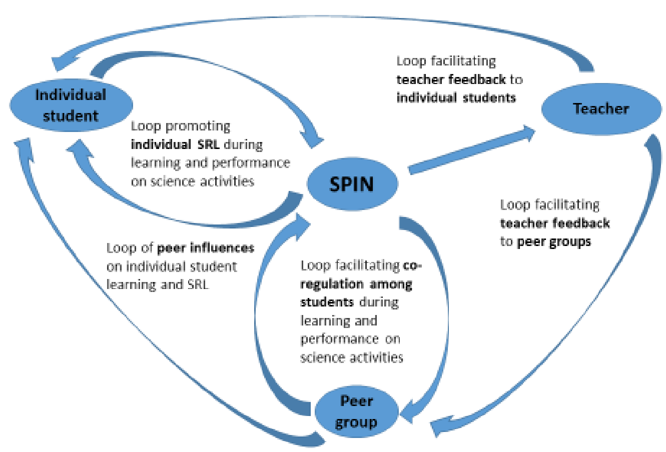
- Collaborate and share expertise on data practices in science instruction, computational thinking, and self-regulated learning
- Develop and implement lesson plans in science that infuse CT and SRL during data practices

Enactment

- Build researcher, practitioner and designer knowledge about learning CT in high school science classrooms from results of lessons
- Design a beta version of SPIN to test in classrooms

Local Impact Evaluation Phase

- Field test SPIN and interpret student responses and learning analytics to provide students improved feedback
- Draft CT learning progression across 9-12



Broad Impact Evaluation Phase

- Scale up and evaluate infusion of CT and SRL in science data practices with SPIN

Informal STEM Teaching and Learning Through Infusing Computational Thinking into Science Learning

(NSF Grant # 1640228)

Dazhi Yang, Ph.D
Boise State University, Boise ID 83725
Email: dazhiyang@boisestate.edu
Website: http://works.bepress.com/dazhi_yang/
Project website: https://sites.google.com/site/stemcproject/

Project Team: The interdisciplinary team consists of six faculty members from four colleges/divisions including a former NASA astronaut as well as four advisory board members and community partners.

- **Boise State University** - PI: Dazhi Yang; Co-PIs: Drs. Youngkyun Baek, Yu-Hui Ching, Steven Swanson, & Sasha Wang; Senior Personnel: Bhaskar Chittoori; Advisory board members: Drs. Brett Shelton & Donna Llewellyn
- **Boise School District** - Mr. Chris Taylor (advisory board member)
- **Boise Parks & Recreation Department**
- **University of Toronto** - Dr. Jim Slotta (advisory board member & external project evaluator)

Description of the Project: The STEM+C program aims to integrate computational thinking (CT) into STEM learning with upper level elementary students in community centers' afterschool programs. The project builds and pilots a **Community Center Afterschool Program (CCAP)** model for integrating CT across K-12 disciplines through the partnerships with the Boise School District and the Boise Parks & Recreation Department that serves high needs, Title I schools in Boise, Idaho. The CCAP model focuses on student learning and problem solving and teacher professional development regarding the integration of CT, involving educational researchers, a school district, Title I schools, community centers, and teachers and students through pre-/in-service teacher-led, project-based, integrated STEM+CT hands-on projects.

The project team has designed and developed **four project-based integrated STEM+CT projects** and implemented each of the projects at two different community centers/schools over **eight weeks** in spring or fall semesters guided by the CCAP module. After the first round of implementation, the project team revised the projects and implemented them for a second time.

- *Life on Mars:* https://sites.google.com/site/stemlifeonmars/
- *Bridge Design:* https://sites.google.com/site/stemboisebridges/home
- *Airplane Design:* https://sites.google.com/site/whydoairplanesfly/
- *Soil Reinforcement:* https://sites.google.com/site/howtomakesoilstronger/

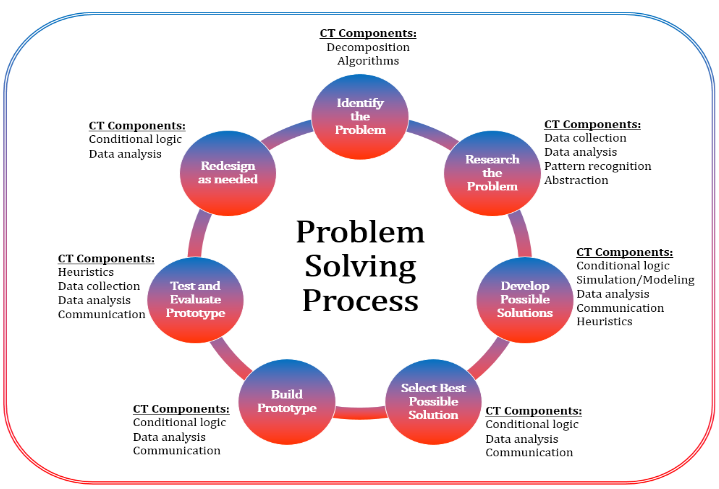


Figure 1: The problem solving process chart

24 in-service and 15 pre-service teachers have participated in the STEM+C project in community center's afterschool program. 10 teachers have implemented STEM+C project in their classrooms. The project has involved more than 140 4th to 6th grade students in six community centers' afterschool programs. An additional 300+ students have participated in an adapted STEM+CT unit in a formal classroom.

Integrated Science Practices Enhanced by Computational Thinking (InSPECT)

Principal Investigators: Sherry Hsi, Peter Sand

Team: Lisa Hardy, Colin Dixon, Sarah Haavind, Tom Farmer

NSF Award: DRL-1640054

Video: https://stemforall2018.videohall.com/presentations/1141

Institutions: Concord Consortium, Manylabs

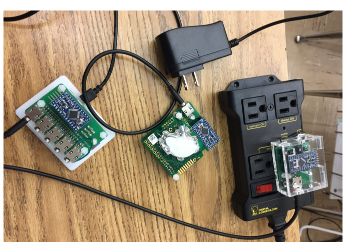
Website: concord.org/inspect

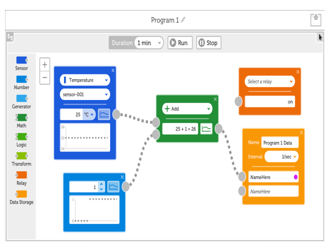
Social Media: @ConcordDotOrg

Contact: inspect@concord.org

The InSPECT project aims to integrate science practices and computational thinking into high school Biology classes through programming for data acquisition and control in the context of laboratory investigations. The project is creating:

- designed activities in which students learn both about Biology and about the tools that produce, transform and store data
- low-cost hardware kits including IoT sensors and actuators
- the Dataflow online programming environment that interfaces with these kits





Research on student learning and teacher practice is guided by the following questions:

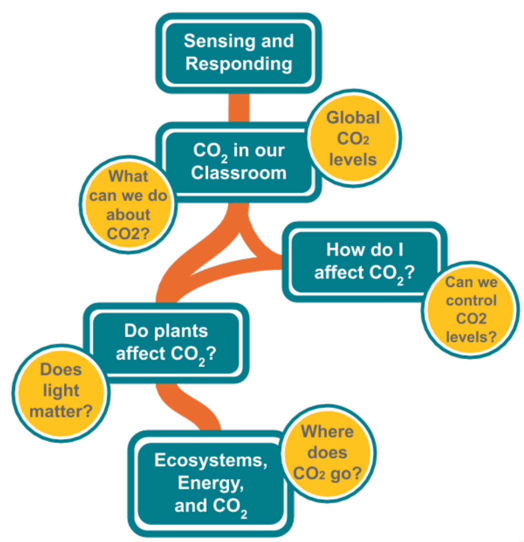
1) To what extent and under what conditions are students able to use the project's computational resources to undertake authentic scientific investigations?

2) When students are engaged in science experimentation made possible by the InSPECT resources, approach, and designed tools, what learning gains will be observed in students' abilities to perform science practices, exercise computational thinking, and understand biology concepts?

3) What kinds of background materials and assistance do teachers require for effective enactments of the intended curriculum?

CT in the Science Curriculum: We view *computational thinking* as a type of reasoning that people do about, and while working with, computational systems. At the same time, we think the idea of *computational participation* is equally important. Contributing to or shaping the computational practices of a community provides the context that makes CT meaningful. The InSPECT activities provide students with opportunities to learn about sensors and computational tools, and to see and discuss data as computational artifacts.

Example InSPECT activity sequence



The Concord Consortium

INTEGRATED STEM AND COMPUTING LEARNING IN FORMAL AND INFORMAL SETTINGS FOR KINDERGARTEN TO GRADE 2

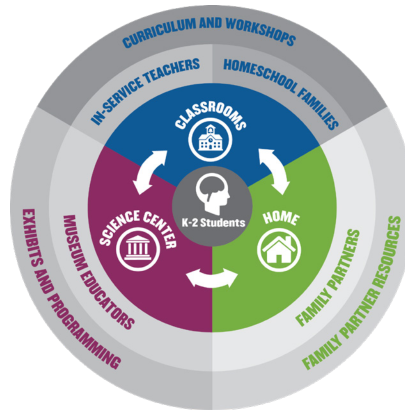
PRINCIPAL INVESTIGATOR: Tamara Moore, Purdue University, tamara@purdue.edu **NSF AWARD:** DRL 1543175

PROJECT RESOURCES: purdue.edu/INSPIRE/Resources **NSF STEM FOR ALL VIDEO:** videohall.com/p/1285

CO-PRINICIPAL INVESTIGATORS: Sean Brophy, Morgan Hynes, Muhsin Menekse, Şenay Purzer, Monica Cardella (former PI)

PROJECT GOALS

To promote engagement in science, technology, engineering and mathematics (STEM) and computational thinking amongst kindergarten through second grade students by developing connections across school-based and informal learning environments.



RESEARCH OVERVIEW

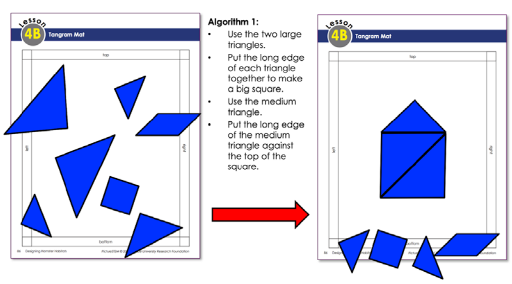
Our research focused on how K-2nd grade students learn STEM + computational thinking while they engage with curricula and science center exhibits.

PROJECT OVERVIEW

- Computational thinking was integrated into three already existing K-2nd grade PictureSTEM units. The research-based, integrated STEM curriculum employs engineering and literacy contexts to integrate science, computational thinking, technology, and mathematics content instruction in meaningful and significant ways.
- Science center exhibits and activities were developed to engage children and their parents in engineering and computational thinking ideas and to connect the in-school learning to out-of-school learning experiences.
- Refined a set of computational thinking competencies and translated them into language appropriate for K-2nd grade educators.
- Defined what it looks like for K-2nd grade students to engage in computational thinking based on in-school and out-of-school observations.

IN-SCHOOL EXAMPLE

In the first grade unit, *Designing Hamster Habitats*, students were asked to help their client Perri's Pet Palace to provide its customers with an enlarged hamster habitat that meets all of the basic needs of a hamster. Computational thinking was explicitly added to the unit through a pair of lessons.. The literacy lesson focused on sequencing the story, which is both a reading and computational thinking learning objective. In the STEM lesson, students used tangrams to further develop their understanding of algorithms. Students follow algorithms and decide if the algorithm will always provide the same results. Finally students write their own algorithms.



CT CONNECTION: Data representation - organizing and depicting data in appropriate ways to demonstrate relationships among data points via representations such as graphs, charts, words or images

Students demonstrated the ability to do geometric translations by organizing and depicting the data (the tangram shapes). Students made relationships and represented the data by building images

OUTSIDE-OF-SCHOOL EXAMPLE

While engaging in the "Computing for the Critters" exhibit's three plugged and unplugged stations, children help a robot find the quickest route to deliver medicine to three animals. At the station pictured below, children pretend to be the robot and deliver medicine (plastic colored balls) by placing them in tubes inside the play structure.

CT CONNECTION: Debugging/Troubleshooting - identifying and addressing problems that inhibit progress toward task completion

While in the play structure, a child delivered the medicine to the animals. After completing the task, the mom and child engaged in the following conversation:

Mom: Was that the fastest way to do that?
Child: I do not know. No, it took a long time.
Mom: Let's see if we can plan better and try fastest ways?
Child: You can time me when I chose both ways.
Mom: that's a good idea, then we'll decide the fastest way.

INSPIRE Research Institute for Pre-College Engineering
PURDUE UNIVERSITY | School of Engineering Education COLLEGE OF ENGINEERING

Integrating Computing into Science Teaching and Learning in Grades 6-8: A Diverse Partnership to Develop an Evidence-Guided Model to Serve Rural Communities

NSF Award #1842359
PI: Susan McKay, Professor of Physics and RiSE Center Director
Institution: University of Maine
For more information, contact project coordinator Marina Van der Eb, Marina.Van@maine.edu
Websites: https://www.mainestempartnership.org/index.php/stem-c
https://umaine.edu/risecenter/

Project Overview

This project develops and investigates an innovative research-practice partnership model for preparing and supporting both pre-service and in-service science teachers in grades 6-8 to teach computing integrated with and applied to the practice of science. The model includes professional learning experiences for teachers, co-design of three modules (one each for grades 6-8) to integrate computing as a problem-solving tool into existing life, Earth, and physical sciences curricula, and implementation, evaluation, and refinement of the modules. We have just completed our first year of work and are preparing to pilot three integrated science/computer science modules in the coming year.

Goals and Objectives

Project goals are to (1) support teachers in integrating computing into grades 6-8 science classrooms, (2) develop and iterate three integrated learning modules, (3) rigorously study how integration affects students' computing knowledge, scientific knowledge, and engagement in STEM+C learning, (4) expand opportunities for pre-service teachers to learn to integrate computing into science teaching and learning, and (5) disseminate our results.

Research Overview

Project research is being conducted through a randomized controlled trial with two cohorts of school districts implementing computer science/science integrated modules on a staggered timeline. Our research focuses on student learning of science and computer science and engagement with/interest in STEM+C learning, and on the knowledge and supports that help science teachers integrate computer science into science instruction.

Evidence

To date, 79% of Cohort 1 teachers have reported increasing comfort in computer science by a full Likert level or more as a result of the STEM+C project. This was a statistically significant shift ($p<0.001$, 2-tailed t-test). Of participants in the summer content immersion and module design experience including teachers, faculty, and graduate students, 94% (16 of 17 respondents) reported shifts in their definitions of computer science.

"This has been a very inspiring process so far. I have learned more than I ever could have imagined and have been so impressed with everyone involved." - Cohort 1 Teacher

RE-MAKING STEM

Integrating Computational Making Practices in STEM Teaching

Principal Investigators **Brian Gravel, James Adler, Tim Atherton**
Tufts University
Eli Tucker-Raymond, Maria Olivares
Boston University Wheelock College of Education and Human Development
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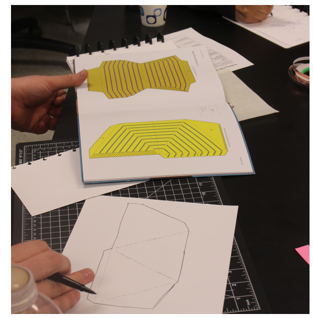


This project designed and implemented a professional development model for K-12 teachers to support their integration of computational practice into STEM classrooms. Using a design principle of *disciplinary computational making practices,* the PD model consists of four-phases of sustained engagement with making: making spaces in which science, technology, engineering, and mathematics (STEM) ideas were linked to play, co-learning with students, the design of classroom units focused on computational making, and their implementation.

The project is guided by research questions focused on how engaging in computational making might shift teachers relationships to (a) their disciplines, (b) to tools and materials for inquiry and making, and (c) to their students. Phase 1 of the PD model involves "computational play," where teachers explore making using familiar crafting materials as well as physical computing and digital fabrication tools to make things in response to simple prompts. Phase 2 of the model asks teachers and students to be co-learners, scoping and addressing problems in their local communities through computational making. Phases 3 and 4 support teachers planning curricular units that feature computational making practices, and data collection as they implement these units in their K-12 classrooms.

What we have learned

Intellectual Humility and Critical Relationality
Teachers reconstruct relationships to students, to ways of knowing, and to making by attending to and cultivating the intellectual authority and right to inquiry of young people. We identified 4 actions that contribute to a stance of IH.

Computational Play
Intersections of play and computation expose opportunities to engage in deep disciplinary practices within contexts of making. Teachers renegotiate relationships to tools through playful forms of making.

STEM Practice as Multiple Conversations
STEM practices are overlapping conversations between self, others, and materials, including computational artifacts. Teachers renegotiate relationships to through multiple interactions.

Centering Students
STEM classrooms can engage students racialized identities by actively Incorporating identities in design projects, making STEM and computing more inclusive

Integrating Computational Science Practice, Weather Data Analysis, and 3D Visualization in the Secondary Earth and Environmental Science Curriculum (NSF Award DRL-1934194)

- Creating innovative science learning pathways by harnessing the data revolution in atmospheric science
- Turning large-scale weather data into unique and exciting secondary science learning experiences
- Infusing computational thinking and practices into modeling, visualizing, and communicating atmospheric processes and changes

Yan Sun (PI), Mississippi State University YSun@colled.msstate.edu
Jamie Dyer (Co-PI), Mississippi State University, JDyer@geosci.msstate.edu
Jonathan Harris (Co-PI), Mississippi State University, JHarris@ngi.msstate.edu
Jean Mohammadi-Aragh (Co-PI), Mississippi State University, Jean@ece.msstate.edu

Target Audiences

- Middle and high school students
- Secondary science teachers

Approach

- Building on the 3D nature of weather data
- Creating unique 3D weather learning experiences
- Developing the ability to access and manipulate data
- Promoting the ability of using computational tools to analyze and interpret data, produce graphical/visual representations of data, and identify key patterns and trends in the data
- Enhancing the competency of applying computational reasoning and model-based understanding to construct quantitative, scientific explanations and predictions about events and processes in atmospheric systems

Project Research

- Adopting a design-based research approach
- Using the convergent parallel mixed methods design
- Collecting quantitative and qualitative data concurrently throughout the project

Curriculum Development

Developing, testing, and validating eight science learning modules that focus on:

- Access and manipulation of large-scale weather data from publicly available sources
- Utilization of IDV (Integrated Data Viewer) to support analysis, visualization and modeling, and interpretation of data to identify patterns and trends
- Computational thinking and model-based reasoning to construct scientific explanations and predictions about atmospheric systems

Professional Development

Developing and implementing 2-week hybrid professional development for secondary science teachers:

Science Teacher Professional Development	
Duration & Mode	2 weeks hybrid (first week online and second week face-to-face)
Training Content	**First Week (online):** ➢ Content knowledge in four themes of atmospheric science: *Energy and Mass*; *Water in the Atmosphere*; *Distribution and Movement of Air*; and *Atmospheric Disturbances* ➢ Computational thinking and practices **Second Week (face-to-face)** ➢ Accessing and retrieving weather data from publicly available online sources (e.g., NAM, GFS, NARR) ➢ Data analysis, interpretation, and visualization with IDV ➢ 3D Weather learning modules related to the four atmospheric science themes ➢ Pedagogies and strategies of implementing 3D Weather learning modules; fostering computational thinking through the modules; creating cultures of thinking and making computational thinking visible; documenting computational thinking ➢ Process and principles of developing one's own computational thinking integrated atmospheric science learning lessons with large scale weather data
Methods & Approaches	Technology-integrated online learning; Interactive lectures; discussions and reflections; hands-on lab and lesson-planning; cultures of thinking; competency building

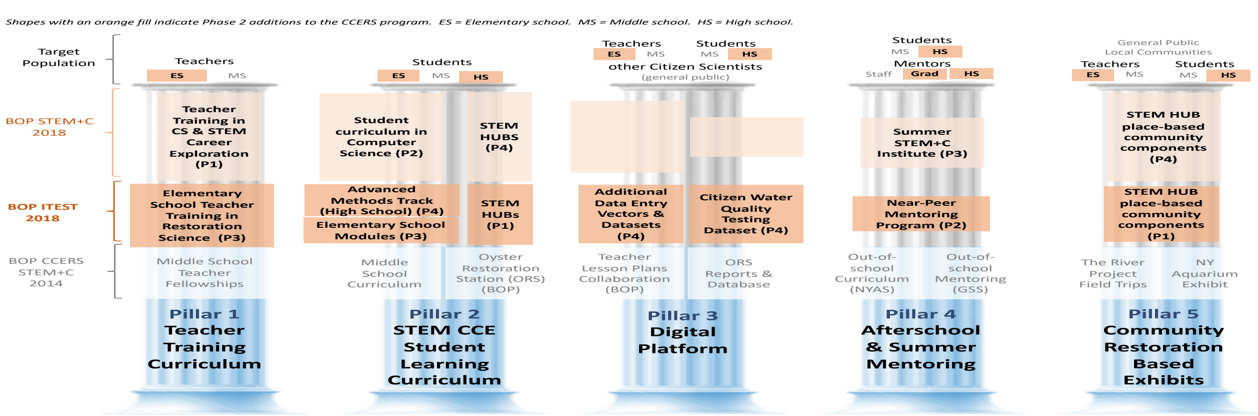
MISSISSIPPI STATE UNIVERSITY

NSF

"Integrating Environmental Restoration Science with Computational Science in New York Harbor with New York City Public Schools" (STEM +C BOP CCERS PHASE III) PI Lauren Birney Pace University New York NSF EHR DRL1839656
lbirney@pace.edu; http://www.stemccers.com/, NSF VIDEO; Twitter Birney, Twitter BOP; Instagram BOP (Year 1)

BOP CCERS Phase III Project Overview: As computing has become integral to the practice of science, technology, engineering and mathematics (STEM), the STEM + Computing program seeks to address emerging challenges in computational STEM areas through the applied integration of computational thinking and computing activities within STEM teaching and learning in early childhood education through high school (preK-12). This project will augment a large-scale design and development project that is testing a model of community-based science education in an urban environment. The existing curriculum model focuses on key concepts in the geological, environmental, and biological sciences that are associated with monitoring environmental conditions and habitat restoration. This project will enhance the existing model by integrating data literacy, computational thinking and relevant statistical concepts and skills into the existing curriculum, enabling students to gain new skills and competencies associated with gathering and analyzing large amounts of field data associated with environmental monitoring and habitat restoration. Data to be analyzed range from basic water chemistry data to data associated with bacterial monitoring and environmental DNA sampling and analyses. *Year 1 (New York City Public Middle School Students Research in New York Harbor)*

Research Overview: The research associated with this project is guided by three hypotheses: (1) Teacher professional learning in data literacy, computer science, and STEM practices will positively influence student outcomes within their classrooms; (2) Teaching informed by teacher professional learning in data literacy, computer science, and science research practices, coupled with teacher and student engagement with scientists will positively influence student knowledge of computational thinking and perceptions of STEM fields and careers; and (3) The project's model of engagement, including problem-based learning, will enhance student awareness of and intent to pursue education pathways to STEM careers. A variety of measures will be used with teachers and students in treatment and comparison groups to test these hypotheses. *(The 5 Programmatic Project Pillars)*



Billion Oyster Project | The Urban Assembly New York Harbor School | Pace University Work toward greatness. | Lamont-Doherty Earth Observatory Columbia University | Earth Institute | Good Shepherd Services We see what can be. | The River Project | NYC Department of Education Carmen Fariña, Chancellor | Fearless | New York Harbor Foundation | Wildlife Conservation Society New York Aquarium | University of Maryland Center for Environmental Science | The New York Academy of Sciences | SmartStart Evaluation & Research

Integrating Computational Thinking in Ecosystem Science Education via Modeling in Immersive Virtual Worlds

NSF Grant# 1639545

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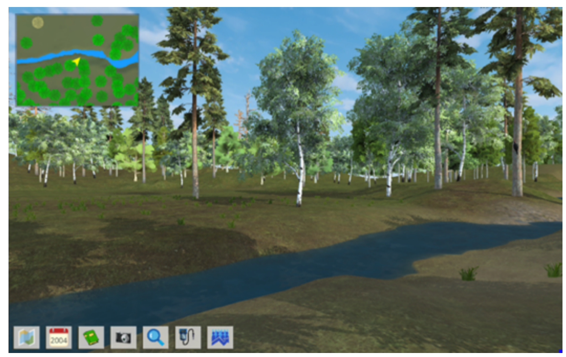
ecolearn.gse.harvard.edu/ecoMOD/overview.php stemforall2019.videohall.com/presentations/1396

Project description: Computational thinking and scientific modeling are essential practices for STEM education. Computational models in K-12 science education can make scientific concepts more accessible and enhance student understanding of phenomena, particularly when students are able to engage in programming scientific models. Visual block-based programming interfaces offer new opportunities to bring computational modeling for STEM learning to elementary school. Immersive virtual environments and computational modeling platforms offer complementary ways to support student engagement and learning.

The EcoMOD 3rd and 4th grade curriculum interweaves an immersive 3D virtual ecosystem and a 2D visual programming and modeling environment to support learning both ecosystem science concepts and computational modeling. The immersive 3D world lets students observe, explore, collect data, and travel in time, in a forest ecosystem that includes beavers building a dam. A point-of-view (POV) tool also lets students "be" a beaver.



With the 2D modeling tool, students construct an agent-based computational model of a beaver building a dam using domain-specific visual programming blocks. As students build and test their models, they observe emergent outcomes in the ecosystem, and make inferences about causal relationships between the elements of the ecosystem.

Impact: Developing advanced scientific and computational knowledge in later grades depends on creating a strong foundation in the elementary school. EcoMOD offers practitioners an effective approach for integrating computational modeling, science content, and inquiry-based practices within elementary science instruction and demonstrates the feasibility and value of immersive learning technologies and agent-based modeling in classroom settings to increase knowledge and interest in STEM.

Findings: Findings from pilot studies show that the EcoMOD curriculum was successful at supporting growth in ecosystems science content, causal reasoning, and computational thinking, while at the same time reinforcing modeling as the practices through which those ideas developed. The EcoMOD curriculum was implemented in classrooms during March-June 2019 with 7 teachers and 150 students; full analysis of that data is currently in progress. Teachers reported high engagement from their students, and felt that the curriculum was feasible and supported students in inquiry-based learning, science content, causality, and programming.

This year we are revising EcoMOD curriculum materials, including lesson plans, teacher guides, and professional development materials, based on teacher feedback and classroom findings. These will be released with a stand-alone version of the EcoMOD software for widespread use under a free research license from Harvard University.

Teacher Professional Development for Embedding Computational Thinking in Mathematics and Science High School Classes (CTPD)

Award number: DRL- 1812982 **Website: https://ctpdonline.org**

PI: Margaret (Midge) Cozzens, Rutgers University, mcozzens@dimacs.rutgers.edu
co-PIs: T. Carpenter & L. Gallos, Rutgers; S. Wilson & B. Montrosse-Moorhead, UConn

Teacher Professional Development for Embedding Computational Thinking in Mathematics and Science High School Classes—or CTPD for short—aims to design and test materials that engage high school teachers from a variety of science and mathematics disciplines to bring computational thinking (CT) into their classrooms. The CTPD project consists of four primary areas of activity: 1) design and development of materials for a PD course in computational thinking; 2) delivering materials to teachers around the country though in-person workshops followed by the on-line course; 3) research testing the efficacy of the professional development delivered; and 4) widely sharing both the online materials developed and research results. The project combines creation of a primarily online PD program with research that explores how well teachers learn CT in an online setting and how and under what conditions they transfer the CT concepts to their math or science classes.

The pilot test cohort included 14 pre-services teachers from Cottey College and 7 in-service teachers

The CTPD professional development course is delivered largely online, but online use is preceded by short in-person workshops for teachers in a local geographic area. The workshops are a critical bridge that serve to introduce teachers to CT, the online platform, and to each other. After the workshop, the professional development continues with 4- or 8-week online programs, creating a hybrid form of PD and a community of teachers learning CT.

Following an 8-week spring-semester pilot test at Cottey College in Nevada, MO, summer courses for high school math and science teachers were launched with workshops in Pittston, PA and Oklahoma City, OK, and an academic year course in Helena, MT. Courses in four other locations will be held in 2019 and 2020.

Teachers work through hands-on activities during the pre-course workshops

Kristi Adams, site director in Missouri says, "I feel amazed that the grant just started September 15 (2018), and now we already have proof it can be successful in different parts of the country. We continue to prove that there's a market for it with 182 applications in OK for 25 slots." Among the findings are: How quickly and enthusiastically teachers were able to incorporate computational thinking strategies into lessons for every age group and across diverse subject matters.

The online course was developed by the Center for Discrete Mathematics and Theoretical Computer Science (DIMACS) at Rutgers University in partnership with the Neag School of Education at the University of Connecticut.

Project Title: DRL:1640135 *Integrating Computational Thinking into Mathematics Instruction in Rural and Urban Preschools*
PIs: Marisa Wolsky (WGBH) marisa_wolsky@wgbh.org, Jillian Orr (WGBH), Heather Lavigne (EDC)
NSF Video Showcase: https://stemforall2019.videohall.com/presentations/1590

Public media producers from WGBH and Kentucky Educational Television and researchers from Education Development Center have teamed up on the project *Integrating Computational Thinking into Mathematics Instruction in Rural and Urban Preschools (DRL* 1640135*)*. Modeled on Clements's (2007) Curriculum Research Framework, the project team is investigating:

(1) What kinds of learning opportunities arise when CT is infused into existing preschool math practices in underserved urban and rural classrooms? What kinds of challenges do children and teachers encounter?
(2) What meaning do young children and their teachers make of prototype hands-on activities and tablet apps that introduce CT concepts and practices into math instruction?,
(3) What does the CT learning process look like in young children when they engage with prototype CT hands-on activities and tablet apps?, and
(4) How does the integration of CT hands-on activities and tablet apps into math instruction impact children's learning of concepts relevant to both math and CT concepts?

To answer these questions, the project team developed a **learning blueprint** and an **alignment document** stating relationships between the learning goals and preschool math instruction. The team then **iteratively developed and tested prototypes of 3 digital tablet apps and 12 hands-on activities** that focused on the **CT concepts** of **sequencing, debugging, and modularity** in ways that leverage children's math skills. After classroom observations with 16 teachers in rural and urban preschools, researchers analyzed observation notes and identified promising practices and areas for improvement for the prototypes. Videos from the classroom visits were analyzed for children's CT learning and teachers' CT understanding related to the CT skills of debugging, modularity, and sequencing. The team also developed and pilot tested a set of learning task interviews to explore children's problem-solving processes using computational thinking.

The following **themes** emerged from the analysis of the observational and video data:

- Children appeared to be very comfortable with the math knowledge required across the set of digital apps and hands-on activities. Likewise, teachers appeared very confident in their strategies to support the math components of the activities.
- It was observed several times that teachers would try to limit the hands-on manipulation of materials before children were given an objective or explicit instructions, seemingly to avoid too much time off-task with the activity's objective.
- Some of the sequencing and modularity activities had goals that were motivated by efficiency (i.e., doing something fast like packing a picnic lunch or getting a character to a goal location in the shortest number of steps). However, it appears that children did not seem to achieve the same level of success when the activities attempted to motivate kids to be efficient. Activities that asked children to supply directions in the smallest units possible (like giving a robot instructions on how to brush its teeth) also appeared to be difficult for young children.

The following **design principles** could be of interest to others who are developing CT resources:

- Allow children time to notice something that may be causing a problem, and then to identify the problem themselves.
- Recognize times that CT is already occurring in the classroom, and then support making those moments formal learning opportunities.
- Consider that solving complex problems may require more than one CT skill, and that the learning of CT skills may benefit from putting one skill in the foreground.
- Provide scaffolds for English Language Learners that allow them to test out ideas, find problems, and demonstrate understanding without a lot of language. This may include using symbols that show what to do, using hand gestures, allowing the manipulation of objects, and providing demonstrations.

This project may potentially provide a model for thinking about how to extend CT into disciplines other than math through the creation of the CT/Mathematics Alignment document. What we are learning about the development of CT learning resources (hands-on activities and tablet apps) could also extend to other types of learning resources that focus on problem solving and intentionality.

Integrating Computational Thinking into the *Insights* Elementary Science Curriculum

This project will develop curriculum materials that promote computational thinking by adapting instructional modules from *Insights*, an elementary science curriculum that promotes students' science sense-making through inquiry, discourse, and reflection.

The Need

Scientifically rigorous, coherent, and developmentally appropriate curriculum materials that integrate science and computational thinking (CT) for elementary students are scarce. This project will address the need for such materials by adapting *Insights*, an NSF-funded curriculum developed prior to the Next Generation Science Standards. These adaptations will realign science content and emphasize the development of science practices, with particular attention to those practices that engage CT.

Our Approach

- Develop and test four units in the *Insights* curriculum, two for grade 1 and two for grade 4. Each module is designed for 8–10 hours of instructional time, comprising roughly 10–12 individual classroom activities.
- Focus initially on CT-rich activities that include opportunities to explore data and work with models and simulations both digitally and non-digitally.
- Develop and test through iterative design-test-revise cycles: each unit will be pilot tested in 6–8 classrooms per grade, then field tested twice in 18 classrooms per grade.
- Provide professional learning opportunities for teachers to provide support for implementing the modules and for recognizing and teaching CT.
- Develop an interactive teacher guide, including annotated artifacts of student work and videos of classrooms in which students are engaged in CT-rich science inquiry, addressing the need for professional learning and implementation support beyond the scope of the project.
- Investigate the impact of digital tools on student CT and science learning. Results of this series of explorations will be used to strengthen CT integration for the revisions and support the development of teacher materials.

Benefits

By focusing on grades 1 and 4, this work creates anchoring points for articulating a developmentally appropriate progression for CT-science integration. Lessons learned during development will generate knowledge about productive ways to integrate CT with science and will identify limitations to effective integration.

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This project is supported by the National Science Foundation under Grant No. 1841189.

STEM21+ CS: Integrating Computer Science Principles into the High School STEM Curriculum

NSF Grant #1741148
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Project Team:
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Dr. Bradley Kjell, Co-PI, Central CT State University
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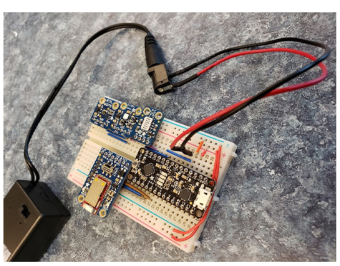
Dr. Kevin Glass, Director of the Center for Program Research and Evaluation at EdAdvance

Description of Project:
STEM21+ CS integrates newly developed Computer Science (CS) learning modules into three existing full-year high school science courses which meet state graduation requirements (Biology, Chemistry and Physics). These CS modules integrated into core high school courses develop and advance students' computing competencies and skills along with their science content knowledge. By integrating CS into required science courses, more students, particularly those underrepresented in CS fields in college and careers, will gain exposure to CS content and will then hopefully elect to take further CS courses. The project addresses the lack of opportunities for underrepresented high school students to learn and apply essential STEM and computing content knowledge and skills that today's workforce demands.

In addition to the CS learning modules, all STEM21+CS students work on an Innovation Challenge Project (ICP)t. Each class functions as business or non-profit, working together to "Research, Develop, Design, and Present" solutions to an authentic challenge in their STEM field of interest. The stages of ICP development in STEM21 courses are expressly designed to help students move into increasing levels of self-management and self-directed learning. The culminating event for all STEM21+CS courses is the presentation of their final products at the annual Student Innovation Expo that hosts over 1,200 students from across CT annually. Projects are evaluated by a panel of higher education faculty and industry professionals in three venues: online, in an exhibition, and as an oral presentation.

Winning Projects from Expo Fest 2019



Wavecheck

A wearable device and app that indicates the user's risk of sunburn and exposure to EM radiation at all times. It also indicates temperature, humidity and UV index. This app can help prevent sunburn, as the students recognized that overexposure to UV rays leads to one of the most preventable medical conditions.

Shelly

Shelly is an app designed by students interested in helping save the turtle population. The app teaches users about sea turtles and suggests ways to help the turtle population thrive. Topics on conservation, the environment and animal habitats were studied while making the app.

Collaborative Research: Integrating computing in STEM: Designing, developing, and investigating a team-based professional development model for middle- and high-school teachers

(NSF STEM+C Grant # 1742332 & 1742351)

PI: Jennifer Albert, The Citadel, jalbert@citadel.edu
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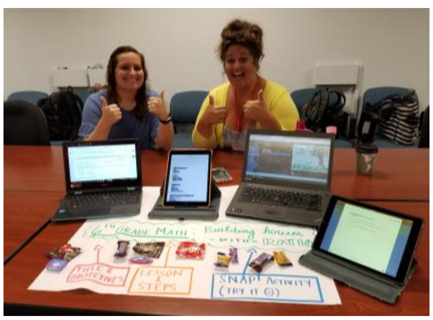
PI: Tiffany Barnes, NC State University, tiffany.barnes@gmail.com
Project Team: Veronica Catete & Marnie Hill, NC State
https://www.infusingcomputing.com/

Project Goals:

- Goal 1: In conjunction with STEM teachers, design and implement equitable computing pedagogies and activities to enhance learning across STEM+C disciplines.
- Goal 2: Understand how contexts (team/individual) and cultures (NC/SC) impact integration of computing into STEM+C disciplines.
- Goal 3: Explicitly connect state/national STEM and computing standards, the school curriculum and the classroom context.



Description of Project:

The goal of this collaborative STEM+Computing project is to design, develop, and investigate outcomes of professional development (PD) designed to support in-service teachers in integrating computing and STEM curricula across middle- and high-school classrooms. Approximately 360 teachers in North Carolina and South Carolina will be recruited to participate in summer PD workshops. This project will explore how PD contexts (e.g., individual or team) and cultures (discipline, state) impact the quality and implementation of STEM curricula integrated with computing.

Research Overview:

The PD will be implemented and studied in three phases, with a particular focus on teacher outcomes, utilizing data obtained through administration of extant instrumentation, interviews, focus groups, video and audio recordings of classroom interactions, and analyses of artifacts. Members of the project team will design new integrated STEM+C curricula; develop standards crosswalks; map the curricula to standards; develop, test, and refine tools (including Snap! programming modules that will help students integrate complex computing and STEM content into creative projects); build and support a community of teachers integrating computing in STEM; and conduct a rigorous comparison study.

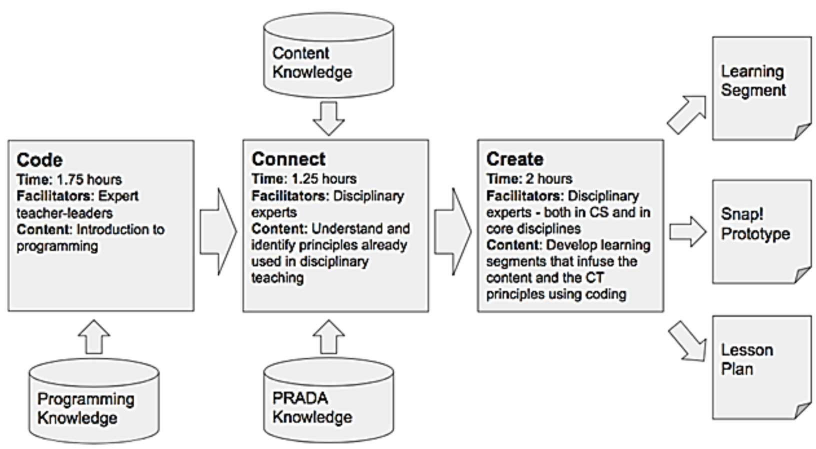


Figure 1. Code, Connect, Create (3C) Professional Development Model

Integrating Meteorology, Mathematics, and Computational Thinking: Research on Students' Learning and Use of Data, Modeling, and Prediction Practices for Weather Forecasting

NSF Award
DRL-1640088

Principal Investigators
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Meridith Brouzas, Co-PI
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Importance

Few phenomena have the salience of weather in our daily lives. Meteorologists must deeply understand data quality and sampling trade-offs, speak the "grammar" of computational models, and be able to characterize the uncertainty of model predictions. Weather and weather forecasting offer an ideal medium for the integration of science, mathematics, and computational thinking, and a prime opportunity for powerful, engaging approaches that significantly change the paradigm for STEM education.

With Argonne National Laboratory, Millersville University, and the University of Illinois at Chicago, we are designing and testing instructional materials and technologies to promote middle school students' ability to apply computational thinking practices and understandings in the context of weather and weather prediction. We are accomplishing this using a novel, highly inquiry-based approach, placing students inside simulated weather phenomena and enabling them to play the role of scientific experts. In this role, students will actively employ computational thinking (CT) practices and skills and science and mathematics understanding as they collect and analyze incoming data, run and refine weather models, and make and evaluate predictions-all within ongoing, quasi-real-time situations. Through this work, we aim to empower students to understand and apply weather-related science and mathematics by employing core computational methods and thinking involving data, models and prediction. This final year will be focusing on rural Indigenous communities in Alaska.

Research

Our research focuses on enacted experiences that lead to science, mathematics, and computational thinking content and understanding and practices and learning environment designs that foster and scaffold these enacted experiences effectively. The research is guided by the following questions:

- What enacted experiences lead to science and CT content understanding and practices?
- What learning environment designs foster and scaffold these enacted experiences effectively?

Integrating Physical Computing and Data Science in Movement Based Learning

New York University and **University of Colorado Boulder**

Kayla DesPortes - NYU - kayla.desportes@nyu.edu
Professor of Human-Computer Interaction and the Learning Sciences
NSF Award: #1933961

Project Description

This project will examine how to integrate machine learning, data science, and physical computing in the context of movement based learning. The project focuses on the design of a learning environment for female high school students who participate in dance and cheerleading. Researchers will explore how to leverage learners' expertise and cultural practices in order to engage them in authentic and personally meaningful computing. The students will learn to create computing systems with programmable electronics worn on the body such as in Figure 1 (physical computing), use those systems to create statistical models of movement and gesture (data science and machine learning), and then apply the models in a digital experiential learning environment. The project investigates how computing can be used to improve the practices of dancers and cheerleaders and expand the ways these learners can express themselves.

Project Phases

Phase I: Interviews and Observations — We will conduct interviews and observations at three development sites including the non-profit organization STEM From Dance in NYC and two cheerleading teams in Boulder, Colorado.

Phase II: Participatory Design Sessions — We will conduct participatory design sessions with dance educators and computing educators to develop a deeper understanding of how physical movement and computing (across the sub-disciplines of machine learning, data science, and physical computing) can complement one another using co-designed physical and computing learning activities.

Phase III: Curriculum Deployment and Iteration — We will pilot the integrated physical education and computing curricula across the three sites in NYC and Boulder. The curricula will consist of four 5-week computing modules that will be iterated on within the three development sites. Three of the modules will focus on each of the computing sub-disciplines individually, and the fourth will involve advanced topics integrating the disciplines together.

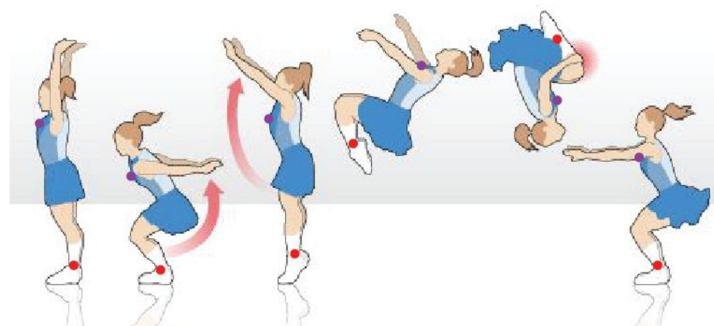

Figure 1. Cheerleader using chest and ankle sensors while practicing acrobatic movements to provide them with feedback based on machine learning training sets they've developed.

Research Questions

RQ1: How can dance and cheerleading education be leveraged to build expertise in computing?

RQ2: What are the challenges of integrating computing into dance and cheerleading practices?

RQ3: How can we meaningfully assess learning outcomes and dispositional shifts with respect to computing in the context of dance and cheerleading applications?

Team

New York University
PI: Kayla DesPortes
Co-PI: Yoav Bergner

University of Colorado Boulder
PI: Ben Shapiro
Co-PI: Michelle Ellsworth
Co-PI: Edd Taylor

STEM From Dance
Co-PI: Yamilée Toussaint

Cheerleading Teams in Boulder, CO

NYU Boulder STEM FROM DANCE NSF

Integrating Science, Mathematics, and Computing within an Elementary and Middle School Pre-Service Teacher Education Curriculum

(NSF Grant #1640041)

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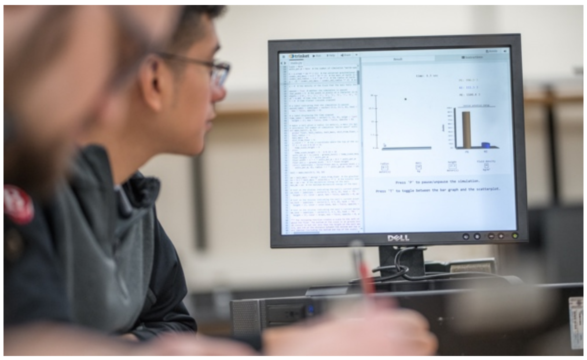
https://videohall.com/p/1384

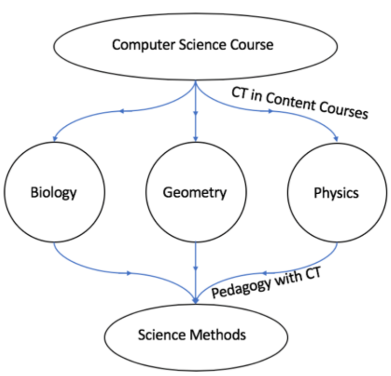


Project Overview

Our interdisciplinary team worked to incorporate computational thinking (CT) and coding modules into courses in the MSTQE program. MSTQE (Math, Science, and Technology for Quality Education) is a Bridge program at Northeastern Illinois University (NEIU) that serves pre-service elementary- and middle-school STEM teachers from NEIU and Chicago City Colleges (CCC).

Approach

We modified the curriculum for our preservice elementary and middle school science and math teachers to include a new Computer Science course and computational thinking modules incorporated into four existing courses.

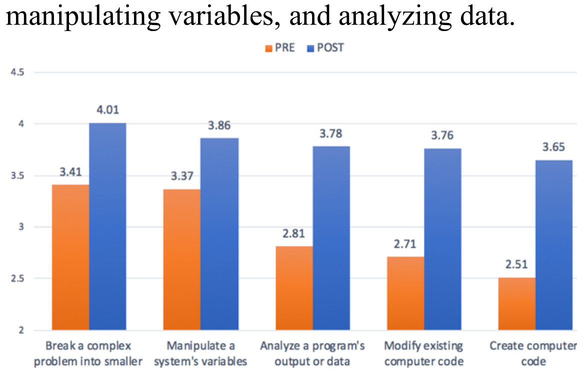


Team Members

Rachel Adler, PI	Computer Science
Joseph Hibdon, Co-PI	Mathematics
Jennifer Slate, Co-PI	Biology
Sudha Srinivas, Co-PI	Physics
Durene Wheeler, Co-PI	Educational Inquiry and Curriculum Studies
Hanna Kim	Teacher Education
Scott Mayle	Physics
Brittany Pines	MSTQE

Results

Students reported growth in their confidence to use CT in their future teaching and careers and their knowledge of CT in general. Students greatest gains were in computational thinking skills, such as modifying and creating code, manipulating variables, and analyzing data.



Visualizing Geohazards and Risk with Code (GeoCode)

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Hee-Sun, Co-PI
Noah Paessel, Co-PI

NSF Award
DRL-1841928

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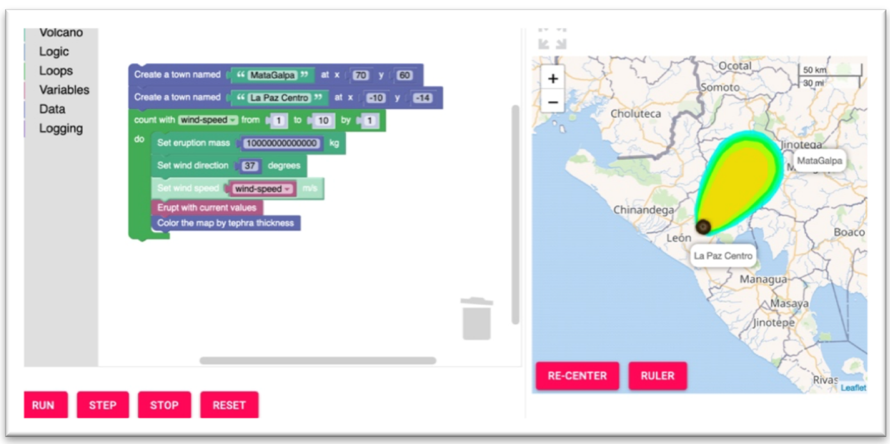
Importance

In 1992, a volcano in Nicaragua called Cerro Negro erupted and released billions of kilograms of tephra over a two-day period. This eruption affected people living near the volcano. Scientists who study active volcanoes like Cerro Negro investigate factors that influence tephra distribution. They simulate eruptions, model past eruptions, and predict impacts of possible future eruptions. In doing so these geoscientists investigate the mechanisms that cause geohazards and the impacts associated with those hazards. Their work helps citizens make informed decisions and take appropriate actions by considering their community's vulnerability and exposure to an impending risk.

The primary goal of this project is to develop a pedagogical model for integrating science practices with computational thinking practices germane to geoscientists' inquiry into geohazards. In this project, core computational practices will occur in the construction, interpretation, and revision of computational visualizations to explain scientific phenomena, make predictions, and assess impacts. Students will engage in the practice of scientific argumentation by using data as part of evidence-based thinking. Our approach will leverage access to real-world data to fundamentally improve teaching and learning of Earth science by integrating key science concepts with the development of code for representing data in accessible visualizations. Through the deliberate, synergistic interweaving of both disciplines, we aim to empower secondary students to explore case studies of real-world geohazards.



GeoCode has been developing the GeoCode Explorer, a block-based programming tool that allows students to program spatially and temporally distributed visualizations. The project is developing curriculum modules that feature the GeoCode Explorer and computationally integrated inquiry-based activities.

Research

Research on student learning is guided by the following questions:

1. How do students translate their understanding of a geohazard into an algorithmic model to create visualizations? How do students interpret data represented in visualizations to improve their understanding?

2. How do students use visualizations they create in formulating scientific arguments to assess risks related to a geohazard?

3. Does GeoCode's curricular approach improve students' understanding of geohazards and data-based scientific argumentation associated with risk assessment?

Integration of Computational Thinking and Science Using Culturally-Based Topics
DRL #1640014

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https://stemforall2018.videohall.com/presentations/1152

Many cultural practices offer a wide array of computational and mathematical ideas and applications. Our team works with Indigenous weavers, urban graffiti artists, Latinx drummers, and others to translate the knowledge embedded in their artifacts and practices into the forms that can be utilized in STEM classrooms. The result is Culturally Situated Design Tools (CSDT.org), an online suite of simulations and supporting materials. Here students learn the original social context; develop coding and math skills by utilizing the "heritage algorithm"; create their own unique version of these patterns in virtual form; and bring that value back to the original communities using digital fabrication and other physical forms. Pilot studies show statistically significant improvement for intervention groups using CSDTs compared to control groups that receive similar software without the cultural content. In the cornrow braiding example:

Lachney, M., Babbitt, W., Bennett, A., & Eglash, R. (2019). Generative computing: African-American cosmetology as a link between computing education and community wealth. *Interactive Learning Environments*, 1-21.

Eglash, R., Babbitt, W., Bennett, A., Bennett, K., Callahan, B., Davis, J., et al. "Culturally Situated Design Tools: Generative Justice as a Foundation for STEM Diversity." In Yolanda Rankin, Y. and Thomas, J. Moving Students of Color from Consumers to Producers of Technology: IGC Global, December 2016.

Babbitt, W., Lachney, M., Bulley, E., & Eglash, R. (2015). Adinkra mathematics: A study of ethnocomputing in Ghana. Multidisciplinary Journal of Educational Research, 5(2), 110-135.

Agricultural Applications of Computer Science

NSF Grant #1742519 **Fall 2017-Spring 2020**

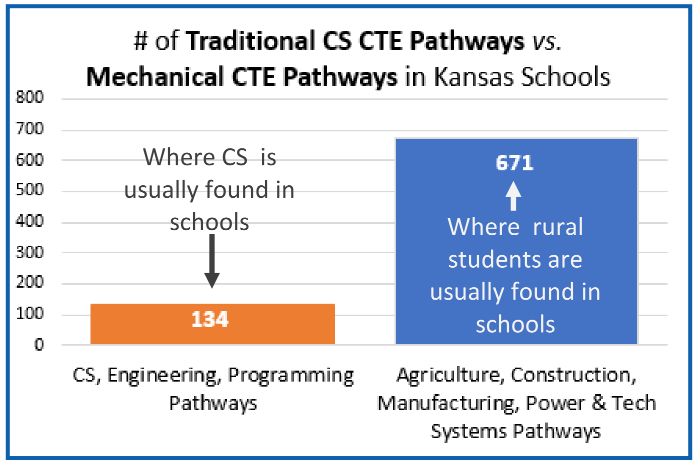
PI: Dusti Howell **Co-PI: Joseph Kern & C. Matt Seimears**

agacsresearch@gmail.com http://bit.ly/getagacs

https://stemforall2019.videohall.com/presentations/1413

The Need

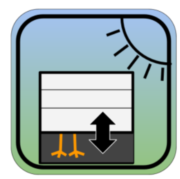
- 20% of U.S. students are rural, with little opportunity to experience true computer science prior to choosing their post-secondary career paths.
- Meanwhile, the Agriculture and Natural Resource industries are extremely high-tech and need technicians and developers who understand both technology and the culture of rural industry.
- Can we improve how rural students are prepared for high-tech STEM careers by incorporating CS into existing courses that are already available in schools?
- Can non-CS teachers in agriculture and traditional science classrooms use ag-related physical computing challenges to integrate computer science and computational thinking into their courses?



Intended Outcomes

- Curriculum of introductory content and 6 agricultural challenge modules: 3 Arduino, 1 MIT App Inventor, 2 Raspberry Pi
- Pilot teacher case study models to aid others in implementing and customizing the curriculum to their own needs, with recommendations developed through the project research
- Student artifacts, unique project prototypes, pilot teacher feedback, and teacher-developed materials to augment the curriculum

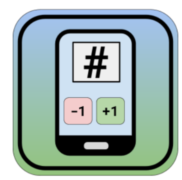
Modules



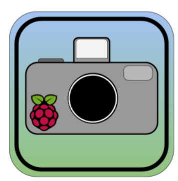
1. Light-Activated Door

2. Moisture-Sensitive Irrigation System

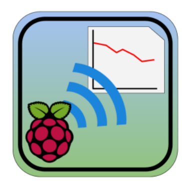
3. Sensor-Activated Cooling System



4. Wildlife-Counting Smartphone App



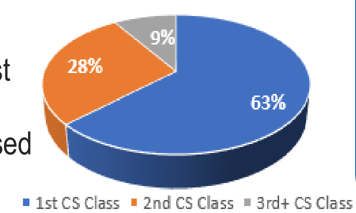
5. Raspberry Pi Camera Projects



6. Logging Data Online

Preliminary Results

- Pilot group of 16 teachers in 11 schools, a nature center, and a zoo
- 91% of students are getting their first or second exposure to CS
- Positive attitudes toward CS increased from 18% to 44% among pilot 8th graders after 1 module
- By incorporating CS into core science and agriculture classes, rather than engineering or robotics-based courses, females make up 49% of pilot students reached
- Curriculum was successfully modified from classroom applications to be used in zoo and nature center day camps



EMPORIA STATE UNIVERSITY

FLINT HILLS TECHNICAL COLLEGE

STEM Teaching Integrating Textiles and Computing Holistically – Project STITCH (NSF #1542801)

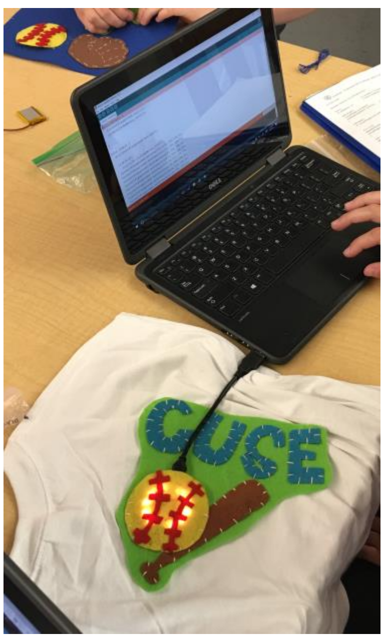
Colby Tofel-Grehl, Ph.D. (PI), Vicki Allan, Ph.D., and Kristin Searle, Ph.D.

Utah State University

colby.tg@usu.edu

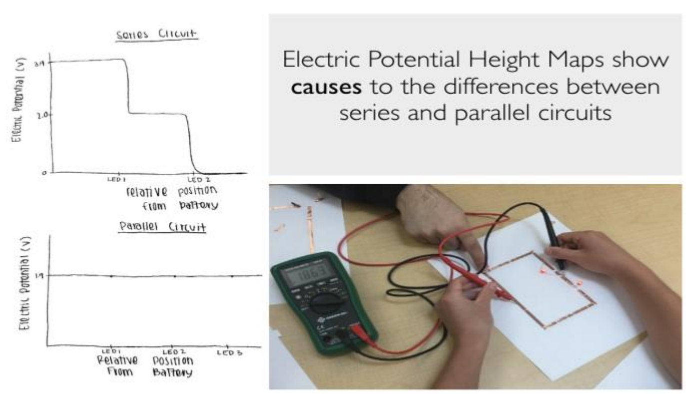
www.ChaosLearningLab.Weebly.Com.

https://stemforall2019.videohall.com/presentations/1349



STEM Teaching Integrating Textiles and Computing Holistically (STITCH) is a curriculum and professional development project that integrates computer science (both hardware and software applications and development) into STEM curricular content to solve a range of authentic problems across disciplines in grades 6-11. The projects require students to program microprocessors to gather and process the data needed to answer a range of STEM associated questions. By sewing circuits using e-textile materials to produce wearable items (e.g. t-shirts, backpacks), students engage in designing solutions that are intellectually rigorous as well as culturally and personally meaningful. The *STITCH* curriculum provides personally relevant context for learning foundational scientific concepts and the computer programming necessary to engage in data collection and analysis processes to solve real world problems aligned with the *Next Generation Science Standards'* emphases on measurement and modeling as vehicles for engaging core concepts. *STITCH* also introduces students to science and engineering practices that align directly with careers in electrical engineering and computer science.

Over 150 teachers were trained using Project STITCH's professional development and curriculum. Over 2,000 of their students designed G-force measuring accelerometer t-shirts, force-sensing backpacks, and temperature sensing lunchboxes. Findings indicate that positive shifts in teacher instructional discourse and choices occur when teaching with e-textiles; these shifts in teacher behavior are correlated with strong gains in students' STEM identity.



Interdisciplinary Approaches to Teaching Computational Environmental Science

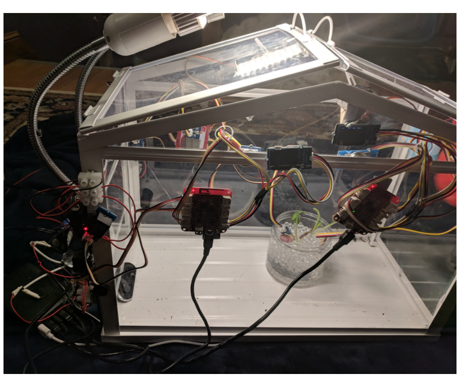
(NSF Grant # 1814001)
Dr. Mike Barnett, PI
Boston College
barnetge@bc.edu, 781-367-2337
http://iuse.bc.edu/

2019 STEM for All Video Showcase: https://stemforall2019.videohall.com/presentations/1643

Project Team:

- Waltham Public Schools, Worcester Public Schools, Springfield Public Schools, MA
- Boston College, Lynch School of Education and Human Development (Dr. Barnett, Dr. Blustein, and Dr. Zhang)
- University of Colorado, Boulder (Dr. Shapiro)
- Iowa State University (Dr. Cademartiri)

Description of the Project: Because of the powerful innovation and application of computing in STEM disciplines, there is an urgent need for real-world, interdisciplinary, and computational preparation of students from the early grades through high school (preK-12). Researchers at Boston College, Iowa State, and the University of Colorado Boulder will train environmental science teachers to use a recent scientific discovery, artificial transparent soil to integrate computational environmental science into their teaching practice. Artificial transparent soil allows for the visualization of roots in living plants and allows scientists, teachers, and students to study root structures and soil ecology on a microscopic level. Mechanically, the artificial soil mimics real soil, supports root structures, holds suspended minerals, can be colonized by microorganisms, and exchanges gases like soil. The project investigators will bring this new computational technology to environmental science teachers in public schools in Massachusetts, Iowa, and Colorado. Teachers will learn how to integrate computational science into their environmental science curriculum and will be immersed in an interdisciplinary training program where they will learn the physics, chemistry, and biological principles underlying artificial transparent soil, while also learning how to program and code micro-electronics and conduct scientific experiments with their students.



Research Overview: The overarching driving question for the research revolves around understanding how and in what ways a supportive professional development ecosystem can be developed that enables teachers to infuse computational science into their teaching that supports their students in conducting scientific research. The project team will utilize design-based research approach that will involve classroom observations, interviews with teachers, and surveys to evaluate how and in what ways teachers adapted the materials to their classrooms. The project team aims to develop case studies of teachers across contexts that will serve as the basis for future professional development. The project team will recruit teachers who teach in under-resourced schools, teach youth of color, or teach in schools with a high percentage of underrepresented populations in STEM fields. The research and evaluation of this program will enable, educators and teachers, to implement best practices regarding the infusion of computational science using a holistic interdisciplinary to STEM instruction.

Computational Thinking in Industrial Automation

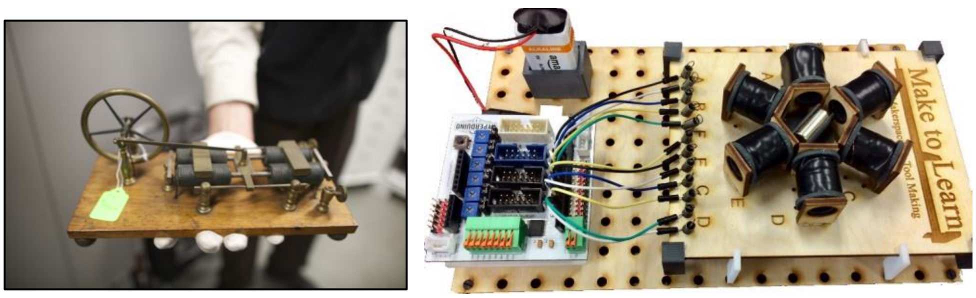
NSF STEM-C DRL-1842342

Glen Bull, Joe Garofalo, & Jim Coohoon., University of Virginia (email: gbull@virginia.edu)

Background. Manufacturing is a critical component of the economy. Industrial automation is driving increased productivity in this sector. This has generated demand for skilled workers to work in automated factories. There is a critical shortage of workers to meet this need. Operation and maintenance of automated systems requires an understanding of both hardware and software. Mechatronics degree programs that encompass mechanical engineering, electrical & electronic engineering, and computational thinking were developed to meet this need.

Goals. Currently fewer than ten percent of students enrolled in mechatronics degree programs are women. The goals of the initiative are: (1) to attract a larger and more diverse group to this field, and (2) to better prepare mechatronics students for careers in industrial automation. This is being accomplished through development of *Invention Kits* to engage students who are not normally attracted to STEM fields.

Invention Kits. The *American Innovations* initiative (NSF DRL-151308), undertaken in collaboration with the Smithsonian Institution, enables students to use school makerspaces to design and reconstruct working models of great inventions in American history.



Charles Page Electromagnetic Engine (1854) and Protoype of Contemporary Stepper Motor Kit

The current initiative will enable students to design working models of the digital counterparts of these inventions For example, the Charles Page Engine, patented in 1854, is being used as scaffolding for development of a *Stepper Motor Kit* that incorporates a digital microcontroller. Students thereby learn about the way in which the analog mechanisms led to development of today's digital counterparts.

Digital Foundation Kits used as building blocks for Digital Arts and Industrial Kits

Foundation Kits	*Digital Arts Kits*	*Industrial Manufacturing Kits*
Year 1 Digital Signal Processor Kit	**Electric Guitar Kit.** Digital signal processing will be used to create digital effects such as reverberation and distortion that transformed the history of rock music.	**Hydraulic Punch Press.** Digital controls will make use of sensors that monitor hydraulic pressures, actuators, and values, taking appropriate actions based on processing of input signals.
Year 2 Programmable Logic Controller	**Light Show Kit.** The relays, timers and sequencers in a PLC will control a light show that can be used in combination with an electric guitar created in the previous year.	**Automated Fabrication Kit.** Programmable Logic Controllers will control a robotic arm to automate the process of loading and unloading a laser cutter to produce components.
Year 3 Stepper Motor	**Kinetic Sculpture Kit.** Computer-controlled motors will be used to create kinetic sculptures with movement, light, and sound.	**Solenoid Winding Kit.** Stepper and servo motors will be used to create a system that will automate the process of manufacturing solenoids.

TIME4CS

Investigating Conceptual Foundations for a Transdisciplinary Model Integrating Computer Science into the Elementary STEM Curriculum

http://outlier.uchicago.edu/TimeforCS/

Broward County Public Schools, Established 1915

outlier RESEARCH & EVALUATION, UCHICAGO STEM EDUCATION | UNIVERSITY OF CHICAGO

Dr. Lisa Ventry Milenkovic, PI
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Broward County Public Schools, Ft. Lauderdale, FL

Dr. Jeanne Century, Co-PI
Outlier Research & Evaluation
UChicago STEM Education

Dr. Lisa Kaczmarzyk, Evaluator

Project Description: This project has been a research-practice partnership between Outlier Research & Evaluation I UChicago STEM Education at the University of Chicago and Broward County Public Schools (BCPS). The project's goal has been to find time for computer science (CS) in the already full elementary day. BCPS' strategy was to embed CS lessons in the non-negotiable literacy time block. To do so, BCPS developed two "transdisciplinary" problem-based learning modules for each 3rd, 4th and 5th grade ("Time4CS" modules) integrating science, reading, and social studies content with CS and computational thinking (CT) concepts. CS and CT lessons were incorporated from Code.org's "CS Fundamentals" course.

The project's over-arching research question was: **"What are the effects of implementing CS within a transdisciplinary curriculum on grade 3-5 students' academic achievement and on their attitudes toward CS?"**

Findings and Outcomes: The findings presented here focus only on analyses pertaining to CS. Analyses demonstrated

- Teachers who taught the transdisciplinary PBL Time4CS modules taught more CS than teachers who did not teach the modules.
- Completing "extra," non-grade-level assigned Code.org CS lessons was associated with higher Achieve 3000, Florida Standards Assessment (FSA) ELA, and FSA Math scores.
- Interdisciplinary teaching practices were positively associated with students' FSA ELA scores.
- Teachers self-reported level of innovativeness was positively associated with students' CS identity attitudes.

Work supported by the National Science Foundation under Grant Number 1542842. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

STEPP Scaffolded Training Environment for Physics Programming

Learning Physics in a Synergistic Scaffolded Programming Environment

NSF STEM+C #1741756

Team

Midori Kitagawa (PI)
School of Arts, Technology, and Emerging Communications (ATEC), University of Texas at Dallas (UTD)

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ATEC/Department of Computer Science, UTD

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Department of Physics, UTD

Mary Urquhart (Co-PI)
Department of Science & Mathematics Education/Department of Physics, UTD

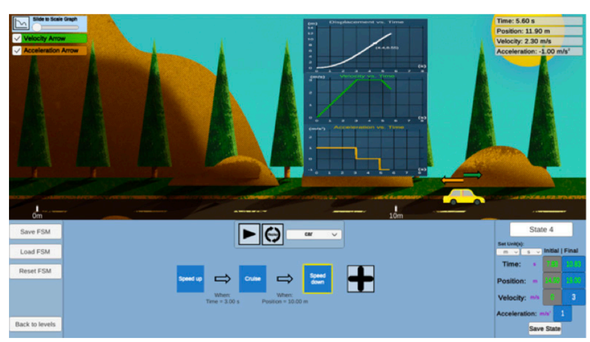
Rosanna Guadagno (Former Co-PI)
Center for International Security and Cooperation, Stanford University

Project Description

The Next Generation Science Standards (NGSS) identify "Developing and using models" and "Use of mathematics and computational thinking (CT)" as two core practices of science and engineering. Although educators, researchers and policy makers widely recognize the importance of modeling and CT, the introduction of these concepts into K-12 STEM education is still in an early stage.

We are developing a **Scaffolded Training Environment for Physics Programming (STEPP)** in which high school students learn physics and cultivate CT skills by creating their own simulation tools, using a modeling tool that is based on the Finite State Machine (FSM) in a scaffolded environment. Our hypothesis is that by constructing their own simulation tools, students learning with STEPP will master physics concepts and computational thinking more successfully than students learning with pre-made simulation.

We will assess the effectiveness of the STEPP modules in on-level high school classes at high schools in the Dallas-Ft. Worth metropolitan area. Our project's progress is detailed "Scaffolded Training Environment for Physics Programming (STEPP): Modeling High School Physics using Concept Maps and State Machines" published at SIGSIM-PADS'19, June 3-5, 2019, Chicago, IL.



Modeling High School Physics Using Finite State Machines

https://stepp.utdallas.edu • midori@utdallas.edu • 972.883.2806

Learning Trajectories for Everyday Computing

NSF Grant # 1932920

Project Team:

PI/Co:PIs: Maya Israel, University of Florida; misrael@coe.ufl.edu
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James Pellegrino: University of Illinois-Chicago; pellegjw@uic.edu
Evaluator: Mega Deiger: Loyola University-Chicago; mdeiger@luc.edu

Website: http://everydaycomputing.org/

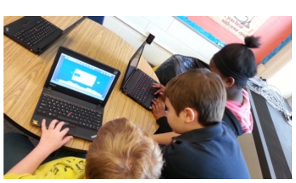
NSF STEM Video Showcase: https://stemforall2019.videohall.com/presentations/1392

Project Description:

LTEC-2 is an NSF STEM+C project that seeks to understand how to integrate computational thinking (CT) into elementary mathematics. This work involves the development and evaluation of integrated elementary mathematics activities focused on fractions in 3rd and 4th grades with CT and computer science (CS) concepts that align to learning trajectories for elementary CT. Our research investigates how students' understanding of fractions is influenced by experiences with integrated lessons that combine mathematics and CT. is a collaborative effort between researchers, staff, and research assistants from the University of Florida, UChicago STEM Education, the University of Illinois-Chicago, and the University of Illinois-Urbana Champaign.

Why This Project Matters:

With the rapid proliferation of CS and CT in elementary schools, there is growing need to understand how to integrate this subject area into instruction. However, there are many questions about how this integration should take place, the effect of integration on disciplinary learning, and the learning progressions that would inform which computational concepts should be taught across the grades. This project seeks to address these issues by (1) designing integrated lessons that can be tested out in elementary classrooms, (2) developing assessments for CT, and (3) investigating whether integrated instruction leads to increased student learning in the area of fractions.



UF College of Education UNIVERSITY of FLORIDA

UCHICAGO STEM EDUCATION

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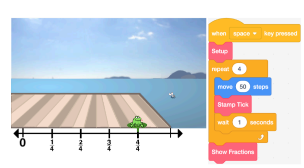


Maker Partnership: A Research-Practice Partnership to Integrate Computer Science and Computational Thinking into Science Instruction

NSF Award # 1742320

About the Maker Partnership

There has been a surge of activity aimed at bringing computer science (CS) learning to all students, particularly those who have been historically underrepresented in the CS field. The Maker Partnership is a collaboration between the Research Alliance, Schools That Can, and MakerState that is designed to build knowledge about how to help elementary teachers integrate computer science and computational thinking into their regular science class using *maker* pedagogy.

The maker approach is based on the engineering design process, with students brainstorming and developing solutions, using technology to create prototypes, and refining those prototypes together. In the fall of 2018, the Maker Partnership began providing curriculum and training to 3rd through 5th grade teachers in eight New York City elementary schools. Teachers implemented afterschool makerspaces in 2018-2019 and will use maker pedagogy in their science classes in 2019-2020.

Project Team

NYU's Research Alliance for NYC Schools	Schools That Can	MakerState
Cheri Fancsali (PI) (cheri.fancsali@nyu.edu)	Arana Shapiro	Stephen Gilman
Zitsi Mirakhur	Roger Horton	Adam November
Sarah Klevan	Casey Lamb	
Edgar Rivera-Cash		

About Our Study

In collaboration with Schools That Can and MakerState, the Research Alliance is evaluating the implementation of Maker Partnership curriculum and professional development, including the extent to which teachers and schools modify the model to meet their specific contexts and needs. We are also examining outcomes for teachers participating in the program—such as CS content knowledge and instructional practice—and the outcomes of students in participating classrooms, including how the curriculum influences student engagement, interest, and learning. Relying on data from surveys of teachers and students as well as case studies, our research focuses particularly on high-poverty elementary schools that serve large numbers of Black and Latino students—students who have historically been underrepresented in computer science and STEM education.

https://steinhardt.nyu.edu/research_alliance/research/projects/maker_partnership

The Research Alliance for New York City Schools

MAKER STATE

SCHOOLS THAT CAN
Where Real World Success Begins

Making Sense of Models:

Investigating Mechanistic Reasoning as a Bridge Connecting 6th Grade Mathematics and Science Learning

Researchers: Irene Lee, Eric Klopfer, Emma Anderson (MIT STEP Lab).
Project GUTS Facilitators: Susan Gibbs, Paige Prescott, and Jennifer Cordova.
Advisory Board: Andee Rubin (TERC); Bronwyn Bevan (RPP Collaboratory); Yasmin Kafai (UPenn); Bob Coulter (Missouri Botanical Gardens).
Evaluator: David Reider, Education Design Inc.

Making Sense of Models was designed to address a problem of practice:

Middle school science teachers find that they have to reteach mathematics concepts to prepare their students to use and analyze computer models of scientific phenomena in their science classes. Some of them find that students do not know why mathematics is useful and how it can be applied in science contexts. Modeling has also become an increasingly emphasized component of both the Common Core State Standards in Mathematics and the Next Generation Science Standards. This project will address these concerns by focusing on mechanistic reasoning in an agent-based modeling environment appropriate for 6th grade mathematics and science classes.

> ***Mechanistic reasoning*** *involves reasoning about how and why a phenomenon occurs, not simply what the phenomenon looks like. Mechanisms can be encoded in computer models where they can be inspected and assessed.*

Audience:

Sixth grade teachers and their students in three school districts.

Intervention:

Teachers will participate in a PD program then teach students to use CT and mechanistic reasoning in math classes and then apply those skills to decoding and modifying models in science classes.

Design Collaborative:

The design collaborative consisting of teachers, facilitators, and curriculum designers will take a DBR approach to developing, testing, and refining:

- a CT focused 6th grade math & science curriculum, and
- a year-long teacher PD program that supports teacher learning and implementation of the integrated curriculum.

Research:

We will conduct case studies of diverse student groups and a quasi-experimental study on the impact of the integrated curriculum on student learning, teacher and student perception of math and CT, and the role of mechanistic reasoning in CT.

We will Investigate how programming solutions to math problems can reinforce mathematical concepts and prepare students for scientific modeling.

NSF Award# DRL-1934126 (Project start date: 1/1/2020)
PI Irene Lee and Co-PI Eric Klopfer, MIT STEP Lab
ialee@mit.edu, klopfer@mit.edu

The PS-Future project is examining the potential for interdisciplinary modules to attract a diverse population of learners to STEM disciplines by engaging them in sustainability topics of broad personal relevance.

Mathematical and Computational Methods for Planning a Sustainable Future II

Award number: **DRL- 1503414**

PI: Margaret (Midge) Cozzens, Rutgers University, mcozzens@dimacs.rutgers.edu, co-PIs: Tamra Carpenter and Hal Salzman, Rutgers University, and Rebecca Jordan, of Michigan State University
Website: https://ctpdonline.org (watch the video).

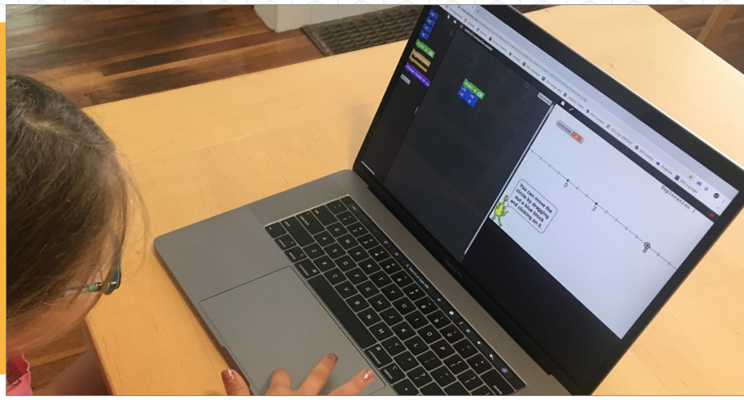
The Center for Discrete Mathematics and Theoretical Computer Science (DIMACS) at Rutgers University PS-Future overarching goal is to develop instructional modules that bring sustainability topics into classrooms in a way that emphasizes the methods and tools of mathematics and computing and illustrates their role in planning for sustainability. The use of modules can allow interdisciplinary themes to be flexibly included in a variety of courses. Through the modules, students learn foundational and emerging concepts in mathematical and computational sciences set in the context of issues relating to physical, biological, environmental, and social sciences. Students develop an increasingly sophisticated understanding of the ways that these disciplines interact through inquiries driven by real problems such as combating invasive species, understanding environmental threats, managing water resources, interpreting weather data, and simply living greener. By exploring real-life problems, students develop an appreciation for the wide applicability of the mathematical and computational sciences, while also becoming immersed in some of the most pressing problems facing the global community.

Photo courtesy of Tamra Carpenter

The project builds on our exploratory project, PS-Future I, to develop, test, implement and disseminate eight new instructional modules for grades 9-12 that emphasize the role of mathematics and computing in planning for sustainability. Presentation within the modules is based on a learning framework that is implemented and tested as part of project research, with the goal of enhancing learning and transfer of the mathematical and scientific content. The project goals are to: 1) conduct research in learning that identifies strategies that can be embedded in instructional materials to promote cognitive transfer by students; 2) produce a set of ten modules in planning for sustainability (eight new and two from PS-Future I) that implement these strategies; and 3) lay the groundwork for a sustainability-aware workforce by making discussion of related employment a part of every module. The project is structured to integrate module development with research so that research informs presentation within the modules, while module field testing provides a forum for research. Our fundamental hypothesis is that conceptual representations can be particularly important for thinking about complex systems and that pairing a conceptual representation with the practice of modeling encourages student transfer of ideas when reasoning about new systems. Project research is helping us determine the extent to which our intervention fosters a more accessible and generalizable understanding of mathematics, computing, and science concepts.

Education Development Center

Math+C: Mathematics through Programming in the Elementary Grades



PIs: E. Paul Goldenberg, June Mark, Deborah Spencer, Kristen E. Reed

October 2019-September 2022

Education Development Center (EDC)

Contact: pgoldenberg@edc.org; kreed@edc.org

www.edc.org

Description and Goals

Working with children and their teachers in grades 3–5, this project investigates the idea that expressing and exploring mathematics through an appropriate programming language may make it easier for a child to engage, enjoy, and learn that mathematics.

Expressing mathematics through programming helps children not only experiment and generalize but gives them a "runnable" notation for their thinking. Unlike writing on paper—which just sits there, correct or incorrect—a runnable piece of code lets children get immediate feedback on their work, which helps their mathematical learning.

The goal is to understand how programming, integrated with elementary students' regular mathematics study, influences mathematical and computational thinking, and to determine whether, and under what conditions, it enhanced children's learning.

National Science Foundation Grant No. 1934161.

Activities and Outcomes

- Investigate a model that integrates programming into elementary mathematics and develops and advances computational thinking
- Develop programming microworlds, unplugged instructional materials, and teacher guides for grades 3–5 to support teachers and students
- Pilot the microworlds and instructional materials in 48 classrooms, testing for feasibility and usability
- Explore how the programming modules influence student mathematical learning and identify features that help or interfere
- Describe challenges to broader use and identify potential solutions
- Provide greater opportunities for a wide range of students to learn in these domains.

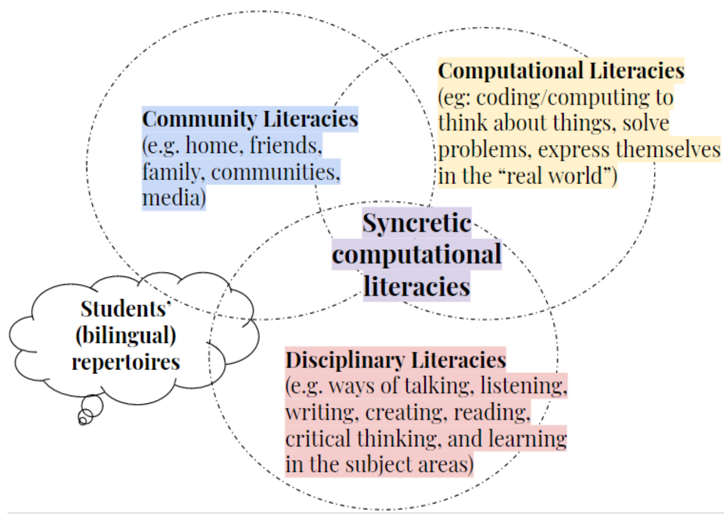
Horizon Research, Inc is the evaluation partner for this project.

Participating in Literacies and Computer Science (PiLa-CS)

Who are we? What do we do? PiLa-CS is a Research Practice Partnership between New York City schools and researchers at NYU and CUNY to support bilingual kids participating in the CS for All initiative in NYC.

- **Practice Goal:** Support K-12 teachers integrating computer science into **bilingual classrooms**
- **Research Goals:** Relate the concepts of **translanguaging** and **literate programming** to the teaching and learning of computational literacies

We incorporate three types of literacies in our designs
We ask, "What conversation is this code a part of?"
We leverage the languaging repertoires that students bring.



Our Lenses. Our project explores how schools can leverage emergent bilingual kids' strengths and experiences by drawing on two lenses:

Translanguaging Theory	Literate Programming
 Bilinguals use their full linguistic and semiotic repertoires including home language, English, gestures, drawing, and more, to make meaning. *(García & Li Wei, 2014)*	 Programs are meant to be read by people, not just computers. Start from human-language representation and massage it towards code + comments. *(Knuth, 1984)*

Web: http://pila-cs.org/ • Video: https://videohall.com/p/1547 • Email: pilacs@pilacs.nyc

Sponsored by the National Science Foundation under NSF grant CNS-1738645 and DRL-1837446. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Project Title: Partnering with Teachers on the Design of Inquiry for Socio-scientific Computational Thinking
Award Number: DRL-1842358
PI(s): Ayush Gupta, Pratim Sengupta, Tara Brown, Erin Sohr, Jennifer Radoff
Contact email: jennifer.radoff@gmail.com

Most major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining and distributing supplies of clean water and food, and addressing other critical environmental problems, are "socio-scientific" in that they are fundamentally social problems that often require scientific solutions. Efforts to integrate these issues into science instruction have not fully succeeded for many reasons. First, because of the intrinsic complexity of these issues, they are difficult to reason about even for adults. Second, there is often inadequate involvement of teachers in initial phases of curriculum development. Finally, the difficulty and discomfort of facilitating classroom discussions on controversial, emotionally fraught issues that don't have single right answers may prevent teachers from bringing them into their classrooms. This project addresses these issues in an integrated way by fostering partnerships between university researchers and classroom teachers at multiple sites (Maryland and Calgary) as they co-design computationally-rich inquiry lessons for students, other teachers, and/or community members.

Breaking from traditional professional development models, which are often hierarchical in nature, this project involves teachers as partners from the beginning, so that all major decisions about the scope and direction of the project can be made collaboratively. Teacher-partners have begun conceptualizing and spearheading computationally-rich, socio-scientific inquiry threads that reflect their own interests as well as their schools' and communities' needs. Over the course of the project, the partnership team will work together to develop these threads into activities and lessons through a process of critical reflection and refinement. The team will also provide intellectual and emotional support to one another, as the inquiry process can be emotionally weighty and riddled with uncertainties.

In the coming we year, we will invite additional teachers to join the team of UMD researchers and elementary teachers. They will join existing inquiry threads or develop new ones. The process of recruiting new teachers to the project is being spearheaded by current teacher team members. This leadership role allows the teachers to have a majority of the say in the expansion of the project, including which teachers are invited to join and what projects the group will support.

As well, research teams from the University of Maryland and the University of Calgary (along with any interested teachers) will address research questions designed to inform theory building about partnership development in the process of collaborative socioscientific inquiry, including the role that computational tools and computational thinking can play in supporting this work. By conducting research in multiple locations, the team will develop insights for how to support teacher-researcher partnerships across multiple contexts, each with its own set of relevant socio-scientific issues as well as structural and material constraints.

*Positioning Youth for Success in Science: Studying the Malleability and Impact of Computational Thinking for Science (*NSF DRL #1838992)

Rena Dorph (PI), Matthew Cannady (Co-PI), & Eric Greenwald (Co-PI)
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Lawrence Hall of Science, University of California, Berkeley
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Project Team: Sara Allan, Lauren Brodsky, Ying-Fang Chen, Melissa Collins, Tim Hurt, Ari Krakowski, Vicky Laina, Ryan Montgomery, Carissa Romano

Project Overview

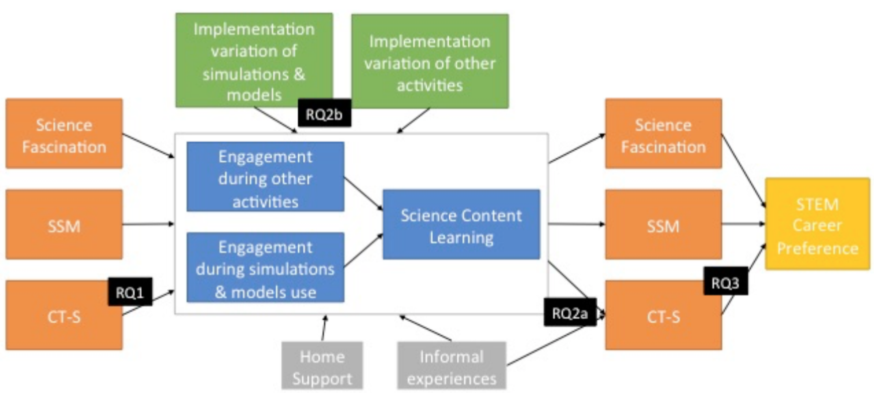
Our three-year project is studying the role that computational thinking plays as both an input into and outcome of science learning. The primary context for this study is a new NGSS- aligned, technology-rich middle school science curriculum, Amplify Science Middle School (ASMS), that has extensive opportunities for students to engage in computational thinking for science. During Year 1, we have synthesized frameworks and definitions of computational thinking (CT) to define the aspects of CT that best position youth for learning science.

Preliminary Framework

	Use a computational tool to:	**Evaluate** a computational tool to determine:	**Design** or **develop** a computational tool to:
Data Analysis	Identify or verify patterns or relationships in data* Gather &/or process data to serve as scientific evidence	How well it works for analyzing data*	Identify or communicate relationships or patterns within data*
Abstractions & Models	Serve as a model &/or generate data to inform predictions or claims about natural phenomena	Its affordances and limitations as an abstraction of a natural phenomenon	Serve as a model of a natural phenomenon or system
Problem-solving*	Test, evaluate, & refine possible solutions to a problem	Its utility for solving a problem	Solve a problem

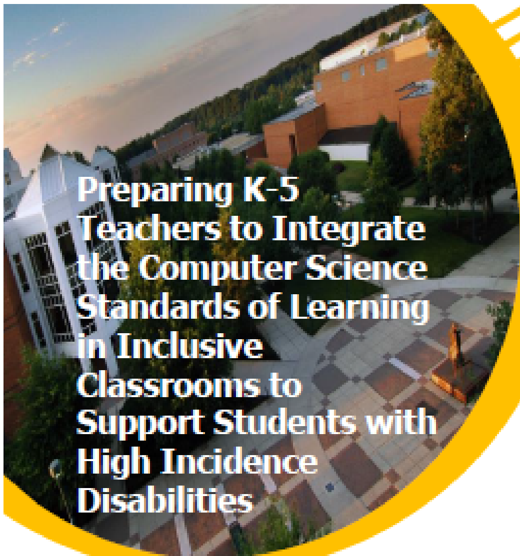
*in a science context

Next, we will test if this construct, *computational thinking for science* (CT-S), positions youth for success in science in technology-rich classrooms above and beyond previously identified dimensions of *science learning activation*: fascination and scientific sensemaking (SSM), that have been shown to predict success in science learning during the middle school years.



Research Questions

RQ1: Across diverse environments and for diverse learners, does CT-S predict engagement and learning in science courses? Does CT-S predict science learning above and beyond scientific sensemaking?
RQ2: (a) Does CT-S change during middle school years? (b) Is there variation in this change based on whether CT-S is taught in science courses? What experiences predict changes in CT-S?
RQ3: At the end of 8th grade, does CT-S correlate with science state test scores and STEM/CS career interest?



Preparing K-5 Teachers to Integrate the Computer Science Standards of Learning in Inclusive Classrooms to Support Students with High Incidence Disabilities

George Mason University

Our Project

Our project is designed for PreK-8 teachers and employs design-based implementation research. The ultimate goal of this work is to provide a school division and educators across the state and nation with a usable, comprehensive, effective, and appealing model of PD to support CS integration, particularly computational thinking (CT) and programming, in K-5 instruction for all learners, with an emphasis on supporting students with high incidence disabilities.

Through exhaustive refinement, this model should sustain an approach that fully supports teachers in this type of instruction. Further, through this work we seek to provide enhanced partnerships between local, government, and state agencies through a collaborative DBIR approach

Our Objectives for this research practitioner partnership are:

1. To determine the challenges faced by teachers in inclusive classrooms when integrating CS into instruction for students with diverse needs, including those with high-incidence disabilities.
2. To determine a developmentally appropriate progression for integrating the Virginia CS Standards of Learning into math, science, and literacy instruction, particularly for students with disabilities.
3. To develop videos and other universally designed instructional materials to support K-5 teachers in inclusive classrooms in integrating the Virginia CS Standards of Learning into their math, science, and literacy instruction, with an emphasis on supporting students with disabilities.
4. To build upon and refine an existing model of professional development aimed at supporting K-5 teachers in inclusive classrooms in integrating the Virginia CS Standards of Learning into their math, science, and literacy instruction.
5. To examine the effectiveness of the professional development for supporting K-5 general education and special education teachers in inclusive classrooms in integrating the Virginia CS Standards of Learning into their math, science, and literacy instruction.
6. To identify effective support methods and adaptations for teaching CS to K-5 students with high- incidence disabilities, incorporating the principles of Universal Design for Learning.
7. To develop theory about how elementary grade teachers develop competencies for integrating CS into their content area instruction.

Old Dominion University

Our Progress

To date we have developed our first cohort of teacher participants, have conducted our first summer institute in which teachers learn about computer science, and have developed all of the assessment instruments needed to measure our progress. Our first cohort of teachers will participate in a range of professional development activities throughout the 2019-2020 school year. We will use feedback and data from these activities to revise our model of professional development for the following year

Contact
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inclusivecomputerscience.org
https://stemforall2019.videohall.com/presentations/1453

PI: Dr. Amy Hutchison (GMU)
Co-PIs: Dr. Jamie Colwell (ODU), Dr. Anya Evmenova (GMU), Dr. Kristie Guttierrez (ODU), Dr. Jeff Offutt (GMU)
Award# 1837380

PRIMARYAI:

Integrating Artificial Intelligence into Upper Elementary Science with Immersive Problem-Based Learning

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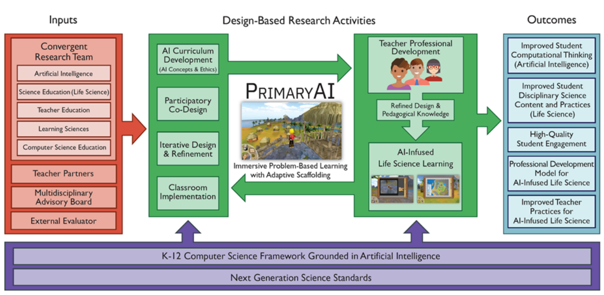
Project Overview

The growing recognition of the demand for an AI-literate workforce highlights the urgent need to develop a deep understanding of how to introduce young learners to AI and how to support teachers in this initiative. PRIMARYAI, an integrated AI-science curriculum and immersive problem-based learning environment, will introduce AI concepts and ethics into upper elementary science classrooms. With a focus on the life sciences in general and ecology in particular, PRIMARYAI will enable students to collaboratively learn about AI by engaging in problem-based learning in which they solve science problems with AI tools designed specifically to support upper elementary students in inquiry-based science adventures.



Team

- Krista Glazewski (Indiana University), PI
- James Lester (North Carolina State University), PI
- Cindy Hmelo-Silver (Indiana University), co-PI
- Bradford Mott (North Carolina State University), co-PI
- Anne Ottenbreitt-Leftwich (Indiana University), co-PI
- Adam Scribner (Indiana University), co-PI

Goals and Objectives

- Design and iteratively refine the PRIMARYAI curriculum and immersive problem-based learning environment that integrates artificial intelligence and life science for upper elementary students
- Create the PRIMARYAI professional development model for teachers that integrates artificial intelligence and life science education
- Provide a social and cognitive account of upper elementary students learning about artificial intelligence and life science through immersive problem-based learning

Year 1 Activities

- Utilize a participatory co-design model with partner teachers to gain insight from activities focusing on knowledge building regarding AI-infused science learning
- Use insights from the participatory co-design activities into the design of the PRIMARYAI learning environment

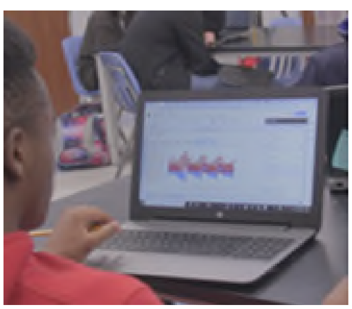
NC STATE UNIVERSITY   DRL-1934128 & DRL-1934153   INDIANA UNIVERSITY BLOOMINGTON

PREDICTS: Principles and Resources for Integrating Computational Thinking into High School Science Courses
NSF Grant# 1741831

Principal Investigator	Daniel Heck, Horizon Research, Inc., dheck@horizon-research.com
Co-Principal Investigators	Joan Pasley, Horizon Research, Inc., jpasley@horizon-research.com Robert Gotwals, NC School of Science and Mathematics, gotwals@ncssm.edu

The PREDICTS project seeks to expand understandings of how (computational thinking) CT can be infused into all high school students' science education. Three research questions guide the activities of this project: (1) How can computational thinking be operationalized in high school science courses? (2) What do high school teachers need to understand and believe to promote computational thinking in their science courses and to teach science using computational thinking? And (3) How can computational thinking integrated into science instruction be rigorously measured?

In order to answer these questions, two biology and two chemistry modules were created in the **Development Phase** of the project. Four teachers implemented the modules and provided feedback in the **Pilot Phase** during the 2018–19 school year. The revised modules will be used in the **Field Test Phase** in 2019–20 with approximately 800 students in seven North Carolina school districts to investigate whether the modules can be implemented successfully across geographic settings and demographic contexts.



PREDICTS researchers will observe a sample of Field Test teachers' lessons, and will interview teachers at the conclusion of each module. Teachers will also complete daily Module Implementation Logs documenting their enactment. The research team will collect student work produced as part of students' engagement with the modules. Using this evidence, PREDICTS is developing and validating instruments for measuring students' opportunities to engage in computational thinking in their science learning, and their use of computational thinking to demonstrate understanding of science ideas.

In addition to the four science curriculum modules, an important project product will be design specifications for curriculum developers and practitioners which outline the process for developing modules to integrate computational thinking in other science topic areas.

The C2STEM environment employs a novel learning-by-modeling paradigm in which students engage in STEM computational modeling and problem solving to promote the synergistic learning of discipline-specific and CS (CT) concepts and practices.

Learning by Modeling: A Collaborative and Synergistic Approach to K-12 Computing and STEM Education

PI: Gautam Biswas, Vanderbilt University
Contact Email: gautam.biswas@vanderbilt.edu

DRL-1640199, Website: C2STEM.org
NSF Video Showcase 2019

HIGHLIGHTS OF OUR WORK

- ★ Challenge-based STEM curricula in Physics and Life Sciences aligned with NGSS & state science standards
- ★ Synergistic learning of STEM and CT concepts and practices
- ★ Classroom studies with over 800 students in 4 states
- ★ Training for more than 30 teachers on classroom implementations of C2STEM

SIGNIFICANT RESULTS

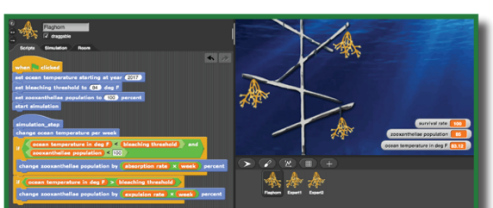
- ★ Significant pre/post learning gains observed in science and CT in both Physics and Life Sciences curricula
- ★ In a classroom experiment (n~100), significantly greater gains for C2STEM vs. control group (traditional classroom instruction) in Physics and CT
- ★ CT and modeling practices learned In C2STEM transferred to problem solving in a new simulation environment
- ★ Evidence of synergistic learning experienced across model-building activities!

WHAT MAKES C2STEM STAND OUT?

Our Learning by Modeling Approach

C2STEM equips students with the ability to build computational models of STEM phenomena, simulate these models to understand behaviors, & apply them to problem solving tasks. Programming the step-by-step process of a model may not only support deeper learning in the STEM domain, but also help students develop CT skills!

From racing sloths to conducting experiments on the effects of gravity, we have added compelling inquiry tools for engaging and motivating Physics learning. In Marine Biology, students work with actual ocean temperature data to understand environmental effects on coral health. Prior to building their own simulations, students can run tests, investigate relations between variables, use important scientific tools, and compare results with expert model code to inspire powerful ideas!



Innovative Assessment Design

To establish effective synergistic learning opportunities, we have created formative and summative assessments using the evidence-centered design (ECD) Framework – enabling us to adapt and align with established educational frameworks.

We design and utilize preparation for future learning (PFL) assessments to provide opportunities to learn from the assessments. PFL measures focus on students' ability and propensity to apply computational constructs and CT practices while learning new STEM topics within and outside of the original C2STEM curricula.

Co-PIs: Akos Ledeczi, Dan Schwartz, Shuchi Grover, Kevin McElhaney **Team:** Nicole Hutchins, Caitlin Snyder, Satabdi Basu, Luke Conlin, Kristen Blair, Doris Chin, Rachel Wolf, Shannon Campe

Research and Design of a Curriculum Authoring System for Computational Project-Based Learning Units in Education (DRL-1543255)

Principal Investigator (PI): Philip Bell, University of Washington, pbell@uw.edu
Co-PI: Trish Millines-Dziko, Technology Access Foundation, trishmi@techaccess.org

Project Focus

We work to support the educational goals outlined in the NRC Framework for K-12 Science Education *with a focus on meaningfully engaging culturally and linguistically diverse high school youth in computational inquiry projects related to contemporary science.*

Goal 1. Develop, study, and refine a curriculum authoring system and the associated co-design practices.

Goal 2. Engage interdisciplinary teams in curriculum authoring, enactment, analysis, and revision.

Goal 3. Research student, teacher, and researcher learning. Explore how project-based experiences might increase students' interest and capability in pursuing computational STEM ecucational pathways.

Goal 4. Develop professional learning resources for teachers' engagement in computational inquiry.

RESEARCH INSIGHTS

- **Curriculum Development:** Principles for interdisciplinary teams developed to understand how to navigate design tensions.
- **Student Learning:** Authentic and unsettled phenomena explored in project investigations supported authentic disciplinary roles and leveraged multiple identities of youth, including as agentic citizens.
- **Teacher Learning:** Novice teachers shifted away from lecture and toward facilitation of learning when students engaged in computational project investigations.

PROJECT RESOURCES PUBLISHED AT **STEMteachingtools.org**

CompHydro

Research on effects of integrating computational science and model building in water systems teaching and learning

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Co-Principal Investigators: Beth Covitt, University of Montana, Beth.Covitt@mso.umt.edu
Kristin Gunckel, University of Arizona, lgunckel@email.arizona.edu
Alan Berkowitz, Cary Institute of Ecosystem Studies, caryinstitute.org

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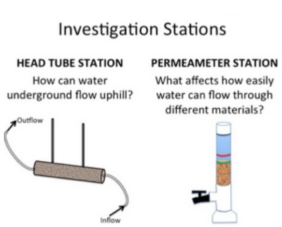
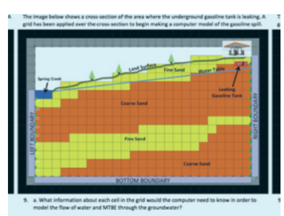
The Comp Hydro project addresses one of the most daunting challenges to developing scientific literacy in students: integrating teaching and learning of key ideas and practices of place-based environmental science with computational and quantitative science in authentic, innovative and effective ways. The basic premise of the project is that in order for students to develop quantitative model-based reasoning in environmental science, their classroom learning experiences need to reflect the practices of real world science – including computational modeling of Earth systems.

- Develop and test instructional modules that integrate scientific and computational learning about hydrologic systems.
- Develop and implement teacher professional development that supports integration of computational thinking and practice into water systems education.
- Investigate how the integration of data modeling and computational thinking into Earth and environmental science courses supports development of model-based understanding of hydrologic systems and use of computational practices to model and interpret data.
- Investigate teachers' experiences and perceptions of integrating computational thinking into instruction in order to learn how to support teachers in engaging in these instructional practices.
- Build a digital support platform to facilitate the development and use of the modules and the proposed research.



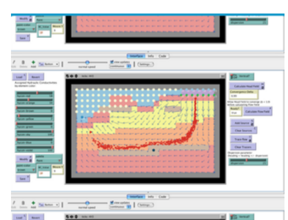
Curriculum

Four modules integrated into Earth system and computational thinking content.



Assessment

View student answers in real time. See dynamic charts of student learning. Keep track of progress.



Modeling

Explore hydrology and computation through NetLogo models.

The University of Arizona College of Education | University of Montana | Bear Center | Baltimore Ecosystem Study | NSF
Colorado State University | Cary Institute of Ecosystem Studies [the science behind environmental solutions] | Shodor a national resource for computational science education

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NSF Award DRL-1543228 ibis-live1.nrel.colostate.edu/CompHydro

Research on Practice Using STEM Inquiry Embedded with Computational Thinking in Elementary School

DRL 1543061. Andrew Elby, University of Maryland. elby@umd.edu
https://sites.google.com/view/umdstemc/

The goal of this exploratory project was to study a professional development model to integrate scientific inquiry and computational thinking in elementary schools, grades 2-6. Specifically, the goal was to embed "unplugged" (non-coding-based) computational thinking in scientific inquiry, both to develop students' computational thinking skills and to enhance their inquiry. Several findings, some preliminary and some more developed, will guide our work going forward.

Teachers refined their understanding of computational thinking (CT). From the start, teachers in our study had some familiarity with CT concepts and practices. However, over 12 months, their conceptions developed from generalized, coarse-grained ideas (e.g., broadly defining CT as problem-solving) to more elaborated and refined versions of these ideas. Another contribution of this work was that the text-based vignettes used to probe teachers' views of CT, which allowed us to probe teachers' thinking more deeply than multiple choice surveys allow.

Integration of scientific and computational thinking draws on metacognition. While investigating biological questions, the teachers stepped back and reflected on their scientific inquiry process to discover opportunities for using CT, often consisting of flowchart-style moves to organize their thinking. The teachers knew these moves *before* engaging in our professional development; but the teachers might have thought to use those particular skills partly because integration of CT into science was "on the table" in this professional development setting.

Computational thinking can facilitate reasoning about socioscientific issues. Educators have argued that CT should be integrated into STEM education partly because CT is useful for thinking about socioscientific issues such as deforestation and the effects of digital technologies on privacy. We found that, when reasoning about socioscientific issues, students and teachers relied on computational thinking practices, emotions, and values in an entangled way; emotions affected which computational thinking practices were invoked, and how. This result raises questions about whether typical depictions of CT in the research literature need to be enriched in order to describe the nature of CT when it's used to address socioscientific issues.

Teachers can think about inequitable classroom participation in multiple, seemingly contradictory ways. CT-infused science activities typically involve small-group work followed by whole-class discussions that can be more free-flowing than typical class discussions. And such discussions can involve inequitable participation patterns, such as some students dominating discussion. Therefore, deep infusion of CT into STEM activities will require teachers to notice and address inequitable participation. When watching and discussing video of a classroom discussion about the behavior of ice, the *same* teachers who initially "diagnosed" certain students as domineering and the teacher as letting the class get "out of control" were also able, to formulate other interpretations—maybe the class was usually quiet and this was the first time an animated science discussion broke out—and to brainstorm ways the inequitable participation pattern could be addressed *without* squashing the discussion. This result suggests that teacher professional development around equitable participation could consist largely of helping teachers activate and "stabilize" knowledge they already possess.

EMMA ECCLES JONES COLLEGE of EDUCATION and HUMAN SERVICES
UtahStateUniversity

Stanford University

(NSF DRL Grant #1842116)
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Co-PIs Jessica Shumway, Utah State University & Victor Lee, Stanford University
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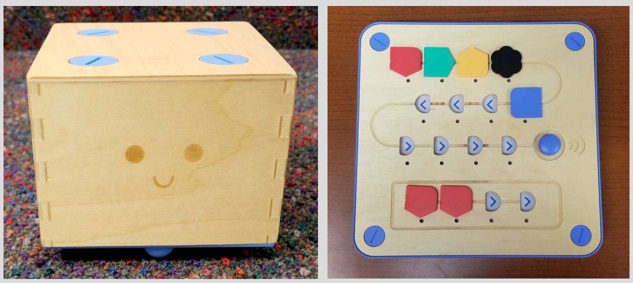
STEM+C: Research on the Development of An Assessment to Measure Kindergarten Children's Abilities to Reason Computationally with Mathematical Problem-Solving Skills



Cubetto by Primo Toys

Bee-Bot by TTS

Code-a-Pillar by Fisher-Price

Botley by Learning Resources

Students are now coming into contact with **programming toys** at a young age. There are claims that use of such toys can enhance problem-solving skills and develop **early computational thinking (CT)**. While many of these early toys are fun and playful, research is needed to understand if programming toys truly support early computer science learning and problem solving. Further, mathematics instruction is one promising space for integrating CT, and it is possible that CT can deepen the **learning of mathematics**. Hence, research is needed to understand the connections between CT and mathematics, particularly in early childhood classrooms. For such work to be possible, early childhood educators need **assessments** that measure integrated mathematics and CT and can quantify learning that takes place with coding toys.

Project goals

- **operationalizing early CT** in kindergarten mathematics classrooms by identifying CT competencies
- **developing curriculum** involving a subset of current early childhood toys around the competencies
- **developing an assessment** to measure students' CT and mathematics competencies
- **conducting evaluation studies** of our curriculum and assessment in kindergarten classrooms

Final products

A competency model of integrated CT and mathematics	An assessment that measures the competency model	Curriculum resources for teachers that leverage toys intended for early childhood settings

Research on the Development of Computational and Systems Thinking in Middle School Students through Explorations of Complex Earth Systems *(NSF Grant # 1542954)*

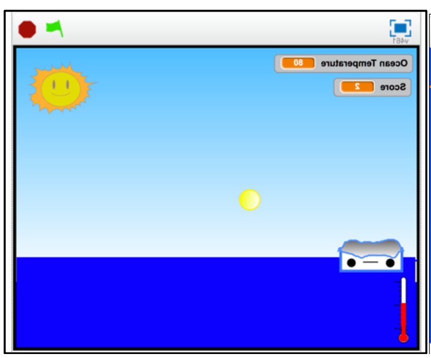
TERC: Gillian Puttick PI (gilly_puttick@terc.edu), Mike Cassidy
Boston University: Eli Tucker-Raymond Co-PI
Northeastern University: Casper Harteveld Co-PI, Giovanni Troiano
Worcester Polytechnic Institute: Gillian Smith Co-PI

Website: buildingsystems.terc.edu
Video showcase: https://stemforall2017.videohall.com/presentations/1003

Goals and Objectives: We created and researched a model curriculum for the integration of computer science into 8th grade learning about climate science via student design of systems-based games. The curriculum was designed to teach students the causes and effects of climate change, strategies for mitigation and adaptation, and the learning and application of CT practices such as systems thinking, modeling, as well as computational problem-solving, related to creating aspects of the climate system in games. Students learned about climate change from a systems perspective, explored existing computer games to identify features related to systems and game genres, and learn to program in Scratch. Student pairs chose a game topic, sketched a model for the game using a storyboard template, then programmed their games, giving and receiving peer feedback in critique sessions.

Evidence of Student Learning: Data from analysis of Y2 games and pre/post assessments show that that students made significant learning gains in climate science, systems complexity, and CT practices. For instance, students' concept maps of climate systems in a post-assessment incorporated more components and connections, and longer causal chains on average, than in pre-assessments. In addition, the analysis of system complexity in 174 student games showed that one-third designed complex systems based on multiple connections, and included feedbacks, or loops. Two examples of student created games that incorporate systems-based approaches are *Albedo Pong* and *Airmania*.

In *Albedo Pong (L),* student designers modeled three systems phenomena: albedo, a reinforcing feedback, and thermal expansion. The game includes rays from the sun (yellow balls), an iceberg as the pong "paddle," the ocean, and a temperature variable, represented as a thermometer. The player manipulates the iceberg to deflect solar rays. In a reinforcing feedback, the iceberg shrinks every time solar radiation enters the ocean and raises the temperature. The ocean level rises if the player allows too many solar rays through.



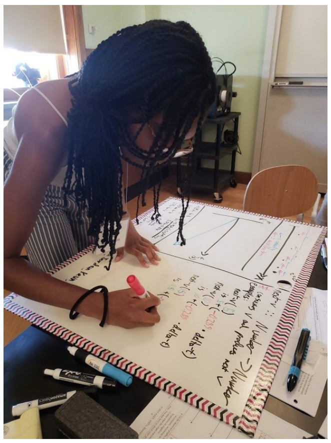
Airmania (R) includes 13 climate components, multiple trade-offs between making money and taking mitigation steps, two balancing feedbacks (e.g., player pays a government official to regulate factories leading to lower CO_2, this balances CO_2 levels caused by a reinforcing feedback, i.e., player invests in factories leading to higher CO_2, increasing global temperature but earning money). Trees can be planted to offset emissions, while cars multiply and must be removed. Effectively, to win the player must develop predictions about what actions will result in what outcomes, thus developing an understanding of the consequences of their choices in relation to other events in the game, and in relation to real-world choices.

Evidence of teacher learning: Teacher interviews and observations revealed that teachers became more student-centered in their teaching out of necessity, in part because they were not familiar with programming, but also because they saw the benefits of supporting student problem-solving, and student reliance on distributed expertise among their classmates. Rather than being a central conduit for expertise in the classroom, teachers found that distributing expertise among students and resources helped teachers integrate complex science and technology tools, and organize student-centered approaches to learning that promoted student agency.

IE: CS for All and Physics for All in Secondary Ed: An Exploration into Bootstrap for Modeling in Physics First, NSF Award #1640791, PI: Robert Hilborn, American Association of Physics Teachers in collaboration with the American Modeling Teachers Association and Bootstrap World
https://aapt.org/K12/Computational-Modeling-in-Physics-First.cfm; contact rhilborn@aapt.org
#compmodeling, #cmpfb, #bootstrapphysics

Computational Modeling Physics First with Bootstrap

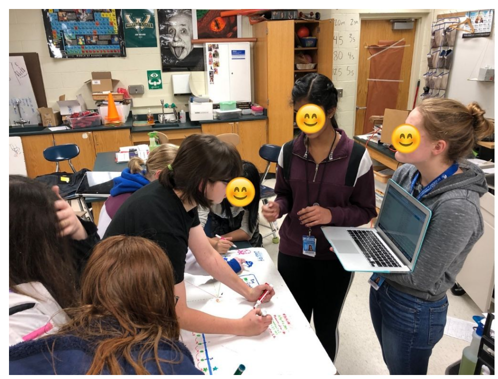
Computational Modeling Physics First with Bootstrap (CMPF-B) integrates computational modeling into freshman-level high school physics. The project attempts to answer two research questions:

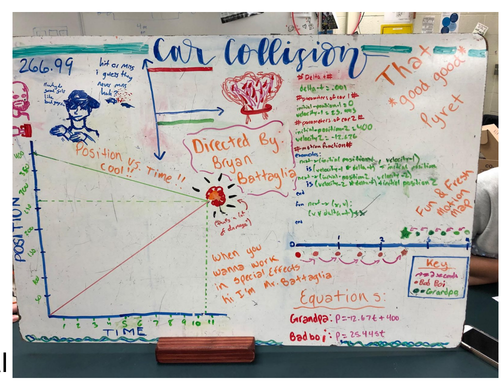


- How does science instruction that integrates computational modeling impact student performance and confidence in the application of computational modeling to solve problems in physics?
- How does engaging Physics First teachers to incorporate computational modeling in their teaching practice impact their curriculum and instruction?

This initiative has worked to create a program accessible to *all* students, and care has been taken to see that it reaches underrepresented and underserved groups. To accomplish this we have merged (1) Bootstrap's computational modeling curriculum for algebra learners, (2) Modeling Instruction physics, and (3) initiatives for Computer Science for All and Physics for All.

Credit: Bryan Battaglia





Our 100Kin10-funded three-week summer training and development session in 2016 taught 12 experienced Modeling Physics teachers to program for the first week. They then used their newly acquired programming skills to develop integrated computational modeling resources to try in their classrooms. In 2017, thanks to the addition of NSF support we expanded this teacher development team to include 30 experienced Modeling Physics teachers. In summer 2018, we held our first dissemination workshop for 23 new teachers, most of whom had no prior experience with programming or Modeling Instruction. In 2019 we repeated this workshop with 24 teachers. In total we have reached 79 teachers and over 2,000 students, and we have 4 trained, experienced CMPF-B workshop leaders. We have identified 4 more leader candidates who are in the training pipeline and will be ready to lead workshops in 2021.

Our project is on track to produce: (1) data on student and teacher confidence in using computational modeling to understand and accurately simulate physical phenomena; (2) data on student and teacher competence in using computational models to represent physical phenomena; (3) scalable, sustainable PD workshops for teachers in both computing and Modeling Instruction that equip them with both an understanding of the requisite programming competencies and a powerful and effective pedagogy with which to impart these competencies to their students; and (4) a comprehensive set of curriculum resources to support both the CMPF-B Workshop for teachers and a comprehensive classroom implementation of computational modeling in the contexts of energy, forces and motion (about a one-semester course in physics).

Research on the Integration of Science, Mathematics, Engineering, and Computational Thinking in Rural Elementary Teacher Professional Development and Effects on Practice

LONGWOOD UNIVERSITY
INSTITUTE FOR TEACHING THROUGH TECHNOLOGY AND INNOVATIVE PRACTICES

LONGWOOD UNIVERSITY
COOK-COLE COLLEGE OF ARTS AND SCIENCES

NSF Grant: 1933717

PI: Paula K. Leach, Ed.D.
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Co-PIs: Ben Campbell, Ph.D., Longwood University, Science
Virginia V. Lewis, Ph.D., Longwood University, Mathematics
Stephanie Playton, ITTIP at Longwood University, STEM

Evaluator: David Reider, Education Design

Project Timeline: January 1, 2020 – December 31, 2022

Institution: Longwood University, Farmville, VA

Project Web Link: https://www.ittip.org/index.php/2019/08/28/nsf1933717/

Project Description:
This project will provide professional development for fourth grade teachers in rural elementary schools who teach both mathematics and science. The project focus is on the development and implementation of strong integrated science, engineering, mathematics, and Computational Thinking (CT) lessons. Teachers will participate in professional development during the first summer focused on content, pedagogy, and the integration of STEM CT. Teachers will be supported during the first school year through coaching while implementing project-designed units using a STEM CT Integration Framework. During the second summer teachers will create their own units for implementation the following school year. Project staff will also support this integration through coaching during the second school year. The project team will research changes in teacher practice as well as self-efficacy when planning and implementing STEM CT curriculum. The project team will also research how students' CT dispositions change when they are taught with an integrated STEM CT curriculum.

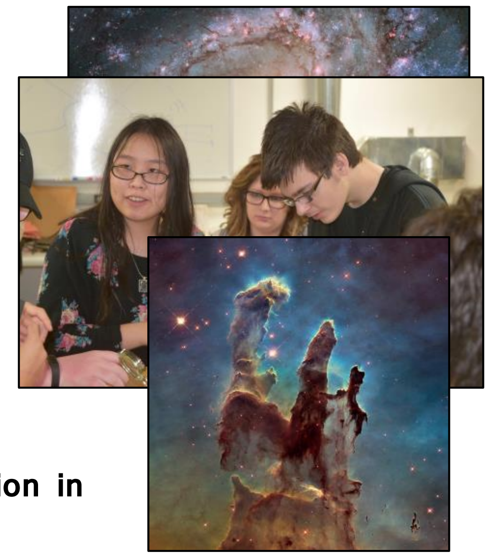
Project Goals:
1) Increase rural elementary teachers' content and pedagogical knowledge regarding CT characteristics and dispositions.
2) Increase rural elementary teachers' confidence in integrating CT concepts as part of transdisciplinary lessons that include mathematics, science, and CT.
3) Improve student awareness of and skill with CT characteristics and dispositions.

Research Questions:
1) To what extent do elementary teachers' practices shift and self-efficacy change when they create and implement an integrated curriculum that includes CT concepts, Science and Engineering Practices and Mathematics Practices?
2) How do elementary student CT dispositions change with the implementation of an integrated curriculum that includes CT concepts, Science and Engineering practices and Mathematics Practices?

Project Title: Research Supporting Multisensory Engagement by Blind, Visually Impaired, and Sighted Students to Advance Integrated Learning of Astronomy and Computer Science

aka – **Innovators Developing Accessible Tools for Astronomy (IDATA)**

Award number: DRL – 1640131
Project Team: Tim Spuck, PI (1) (tspuck@aui.edu); Jim Hammerman, Co-PI (2) (jim_hammerman@terc.edu); Dan Reichart, Co-PI (4); Andy Stefik, Co-PI (5); Patrick Daleiden (5); Santiago Gasca (2); Alexandra Grossi (1); Kathy Gustavson (1); Josh Haislip (4); Eric Hochberg (2); Tyler Linder (1); Kate Meredith (3). Evaluator: Bret Feranchak (6). (1. Associated Universities, Inc. 2. TERC, Inc. 3. GLAS Education. 4. University of North Carolina, Chapel Hill. 5. University of Nevada, Las Vegas. 6. Logos Consulting Group, LLC.)
PI Contact Email: tspuck@aui.edu
Website: http://www.idataproject.org
Link to 2019 NSF Video Showcase:
https://stemforall2019.videohall.com/presentations/1609



- **Exploring computational thinking and learning in astronomy**
- **Understanding the impact of engaging students in authentic software design/development**
- **Inventing blind and visually impaired (BVI) accessible image/data analysis software**
- **Developing curricular resources to support computation in astronomy and software use**

What's IDATA? Perhaps you've seen those spectacular images from the Hubble Space Telescope: pillars of greenish gas and dust giving birth to new stars and planets, incredibly detailed spiral arms in galaxies millions of light-years away, but you can't look through a telescope and see these amazing wonders of nature. Light from these distant objects is converted into numerical data and computers use that data to generate the images we see. In reality, we are all "blind" to this data. We simply choose to convert these numbers into images, but there are other ways, beyond our eyes, to analyze this data.

Typical astronomy software that displays data visually, presents unique challenges for blind and visually impaired (BVI) individuals. IDATA will change all of that. Over the next two years this nationwide project will partner BVI and sighted students and their teachers, astronomers, computer scientists, software engineers, and education researchers to explore computational thinking in astronomy and to design and develop a fully-accessible software tool; making astronomy accessible to the blind and visually impaired.

Education Research Summary: IDATA is funded by the US National Science Foundation STEM+C program, and will work to advance knowledge and understanding of best practices in teaching and learning related to computation and computational thinking in astronomy and how participation influences students' attitudes and beliefs about who can engage in science, technology, engineering, and mathematics (STEM) and computing. The accessible software and instructional modules and hands-on activities produced by the project may be adopted by a range of BVI and sighted individuals, but may also be transferrable to other similarly visually-intensive domains such as satellite, geophysical, and medical imaging.

Multilevel Computational Modeling

SAGEMODELER

NSF Awards
DRL-1842035
DRL-1842037

Institutions
The Concord Consortium (CC)
Michigan State University (MSU)

Principal Investigators
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Joe Krajcik, PI (MSU)
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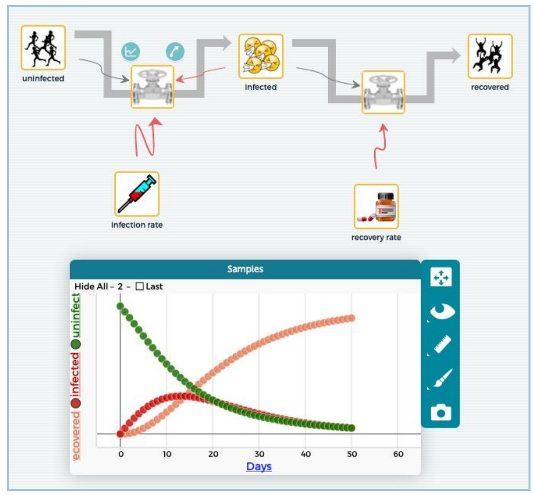
The Concord Consortium and Michigan State University are collaborating to research and disseminate technological, curricular, and pedagogical scaffolds needed to support secondary students' engagement in computational thinking in the context of system modeling for exploration of phenomena across multiple STEM disciplines.



Systems thinking and modeling are essential for addressing some of our most challenging scientific and societal problems. Climate change, human health and physiology, and economic policy are all examples of problems that require a systems approach. Solving problems or exploring phenomena through the development and use of systems models requires computational thinking, not only by software programmers, but by the entire team working on a problem.

Simulations of system models traditionally involve programming and/or the development of mathematical equations to define relationships between variables. While programming may be essential in solving scientific and engineering problems, designing a model or a plan for data analysis involves computational thinking, which should be accessible to all. Having students engage in system modeling without requiring the writing of traditional code or equations provides a powerful and more accessible platform for engaging in computational thinking, one of the eight key scientific and engineering practices in the NGSS.

SageModeler is the software platform we are developing and studying that facilitates student construction of systems models. We're extending SageModeler to support systems dynamics modeling and adding the ability to tag models with characteristic features (e.g., feedback loops) to facilitate class discussions; creating curriculum units for students to engage in building, testing, sharing, evaluating, and revising models of increasing complexity; and developing teacher resources, including a professional learning community.

Research

Project research focuses on how students' modeling practice and computational thinking co-develop. Our research questions:

- How are students' scientific explanations informed by the computational thinking they engage in during iterative development of system models?
- In what ways can curricular materials and technological tools best scaffold the development of students' computational thinking and system modeling practice?
- How can teachers scaffold the construction and simulation of computer models to more thoroughly engage students in computational thinking practices?

MICHIGAN STATE UNIVERSITY

CREATE for STEM Institute

The Concord Consortium

Science And Integrated Language Plus Computational Thinking and Modeling with English Learners (SAIL+CTM with ELs)

NSF DRL-1742138

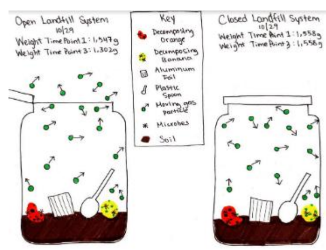
Okhee Lee, PI, New York University, olee@nyu.edu

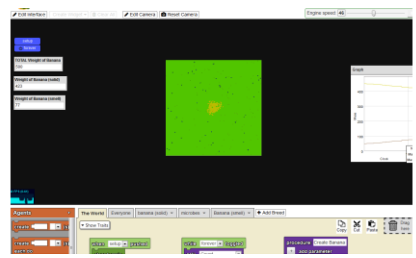
https://www.nyusail.org/projects-all

The project builds on and synergizes two ongoing projects: Science And Integrated Language (SAIL), a yearlong fifth-grade NGSS-aligned curriculum with a focus on English learners (ELs), and StarLogo Nova, a blocks-based programming environment with an agent-based simulation engine for modeling complex systems. The goals are (1) to develop the SAIL+CTM curriculum by expanding and refining SAIL through integration of computational thinking and modeling (CTM) using StarLogo Nova; (2) to investigate feasibility of implementing the curriculum in classrooms, and (3) to investigate the extent to which the curriculum promotes student learning outcomes in both science and CT.

In each of the four curriculum units throughout the school year, fifth-grade students make sense of phenomena and represent their ideas using physical, diagrammatic, and computational models. For example, in our first unit “What happens to our garbage?” students engage in the practice of modeling to explain the decomposition of garbage materials and the conservation of weight:







The following research questions with a focus on ELs are examined:

Feasibility of implementation:

1. To what extent and how do elementary school teachers support students’ engagement in CT?
2. To what extent and how do students engage in computational modeling?
3. What design features of the curriculum and software support students’ engagement in computational modeling?

Student learning outcomes:

4. How do students’ understanding of causal relationships underlying phenomena evolve as they engage in physical, diagrammatic, and computational modeling over the year?
5. How do students’ understanding of key aspects of CT evolve over the year?

The project consists of three phases. In Year 1, we enhanced StarLogo Nova in the context of SAIL+CTM and developed draft versions of the curriculum. In Year 2, we entered an iterative field-testing phase wherein we implemented the draft curriculum in classrooms to investigate feasibility of implementation. In Year 3, NYU will examine feasibility of classroom implementation and student learning outcomes when the revised curriculum is implemented across a larger sample of classrooms with varying compositions of ELs. Multi-cycle design studies at Vanderbilt will examine the affordances of curricular innovations to support development of students’ science learning and CT with a microgenetic lens.

New York University: Okhee Lee, Lorena Llosa

Massachusetts Institute of Technology: Eric Klopfer, Daniel Wendel

Vanderbilt University: Corey Brady, Doug Clark

Horizon Research, Inc.: Dan Heck

Science Modeling through Physical Computing:

Contextualized Computational and Scientific Learning in the Grade 5-6 Classroom

Award #: DRL 1934113
Principal Investigators: Francis Quek, Texas A&M University: quek@tamu.edu
Sharon Lynn Chu, University of Florida: slchu@ufl.edu
Co-Principal Investigators: Rebecca Schlegel, Texas A&M University: beccaschlegel@tamu.edu
Joanne Olson, Texas A&M University: jkolson@tamu.edu
Christina Gardner-McCune, University of Florida: gmccune@ufl.edu
Project Dates: January 2020 - December 2023

Project Overview

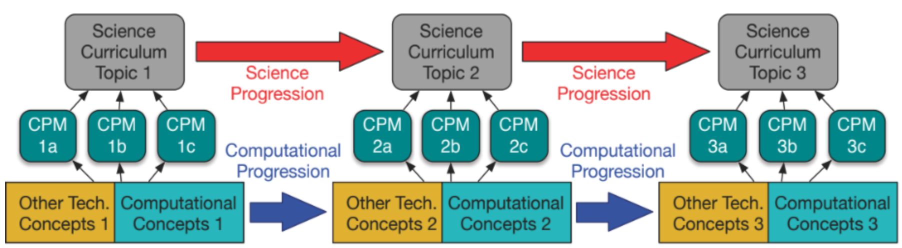
This new STEM+C project addresses the engagement of students in Science Modeling through Physical Computing (SMPC) to build science models to learn both science and computing in grade 5 to 6 classes. Students will engage with computation to imbue physical models with functionality to represent various state, static, dynamic, and semantic scientific phenomena.

Implementation Approach

To allow students to engage in both science modeling and physical computing simultaneously under the constraints of the formal public school classroom we have developed a *double-scaffolding strategy*, shown in the figure. The strategy entails two scaffolds:

(1) **Scaffold A:** Science learning is scaffolded through students' construction of Computational Physical Models (CPMs) to support understanding of formal science topics, and to inculcate model-thinking.

(2) **Scaffold B:** A second scaffold supports a learning progression in computing to build the CPMs. This scaffold is practice-oriented, with new concepts added as required to complete each set of CPMs.



Population

The work will be conducted in two public high-needs intermediate schools located in the Bryan Independent School District, TX:

- Jane Long Intermediate School
- Sam Rayburn Intermediate School

The project will reach at least 600 students over 2 years in grades 5 to 6, a crucial age for STEM learning and identity formation.

Research Goals

The project will study the impact of SMPC on:
1) more robust learning of science concepts through modeling;
2) constructionist learning of computational concepts and the acquisition of computational thinking as a habit of mind, and
3) the development of identities in both science and computation.

Both research and school collaborators are welcomed.

SciGirls

- SciGirls Code: A National Connected Learning Model to Integrate Computing in STEM Learning with Middle School Girls
- NSF Award #1543209
- Joan Freese, PI; Rita Karl, Co-PI; Karen Peterson, Co-PI; Cassie M Scharber, Co-PI
- Twin Cities PBS
- jfreese@tpt.org
- https://scigirlsconnect.org
- https://stemforall2018.videohall.com/presentations/1105
- https://twitter.com/SciGirls | https://www.facebook.com/scigirlstv/

SciGirls Code, funded by the National Science Foundation's (NSF) STEM + Computing Partnerships (STEM + C) program, used principles of connected learning with 16 STEM outreach partners to provide 160+ girls and their 31 educators with computational thinking and coding skills and experiences. Connected learning is a learner-focused approach that harnesses the advances and innovations of our connected age to serve learning. The approach seeks to integrate three spheres of learning in young people's lives: peer culture, interests, and academic content.

SciGirls Code was comprised of a 9-month curriculum centered on 3 tracks—mobile apps, robotics, and e-textiles; role model training for female technology professionals and professional development for STEM educators. External evaluation by Educational Development Corporation found the educators were positively impacted by participation, learned about CS, how to facilitate the curriculum, and how to build girls' computational thinking skills. Data showed role models using effective strategies for engaging girls made positive connections with girls.

Research Study: A University of Minnesota research study investigated the ways computational learning experiences impacted the development of computational thinking as well as interest and attitudes toward computer science (CS). This study utilized an interpretive case study design to answer 3 questions: 1) How do computational learning experiences impact the development of computational thinking? [*learning*]; 2) How does engaging in computational learning experiences impact interest in and attitudes towards computer science? [*interest*]; and 3) How does engaging in computational participation practices impact perspectives of self and world? [*participation].* Eighty-four (84) girls across 11 programs were included in the research study. Data included pre/post program surveys, interviews, observations, and artifacts.

Research Findings: Girls gained new perspectives on computing, cultivated computer science skills (including coding), and utilized computational thinking. Challenges were critical to girls' learning and deepening understandings of and skills related to computing practices. Girls identified collaboration and the girls-only environment as key parts of their CS learning experiences. The process of remixing in order to get a working product led to feelings of pride and accomplishment. While all participants did not want to be computer scientists, they finished the program with knowledge of how to engage with and participate in the technology that surrounds them, as well as a better understanding and articulation of their evolving computational identities.

SciGirls Code showcased the positive outcomes of combining the core tenets of the connected learning model with the concept of computational participation. Interest-powered learning choices, the production-centered curriculum, and the peer-supported environment provided opportunities for more equitable participation as girls were given the freedom to explore their interests as they experimented and produced meaningful CS artifacts. The program structure allowed girls to incorporate aspects from their social and cultural contexts to meaningfully engage in computational participation. These findings demonstrate how an increase in interest, collaborative environment, and (sustained) positive attitudes toward computer science can pave the way for future learning and career choices, which is significant in light of the persistent underrepresentation of women in computer science.

Programs like *SciGirls* Code provide an example of how to encourage and nurture interest in STEM-related activities with middle-school girls so that they enter high school years having experienced confidence, collaboration, engagement, and success in STEM experiences which could impact their interest in STEM careers.

Partners: National Girls Collaborative Project (NGCP); University of Minnesota Learning Technologies Media Lab; *SciGirls* CONNECT partner programs; and an advisory board of practitioners, CS researchers, and learning scientists.

STEM Integration in the Digital Forensics Science Learning Environment (DFSLE) for Grades 9-12

DRL STEM+C Award #164017
Eoghan Casey, Principal Investigator I Digital Forensics Solutions / Cyber Sleuth Science Lab
Daryl@digitalforensicssolutions.com I www.cybersleuthlab.org
2019 NSF Video Showcase: https://stemforall2019.videohall.com/presentations/1620

Project Overview:

The Cyber Sleuth Science Lab (CSSL) is a virtual learning environment that introduces young women, underrepresented and underserved high school students in grades 9-12 to concepts and careers in Digital Forensic Science and Cybersecurity. Lessons focus on fundamental Digital Forensic Science concepts, Privacy and Digital Citizenship and how student can apply these ideas to the world around them. Students are cast in the role of an investigator and assigned real-world scenarios - missions. In these missions, they uncover clues and examine evidence to answer investigative questions.

Project Goals and Objectives:

Inspire more young women and underrepresented students to pursue education and careers in Digital Forensics and Computer Science * Develop a STEM learning environment well suited to these students by immersing them in a process of computational thinking, scientific inquiry and problem solving in the context of complex social issues. * Teach "digital street smarts" to help these students develop digital literacy and 21st century skills, by familiarizing them with online risks and laws, and encouraging responsible and safe behavior in a digital society.

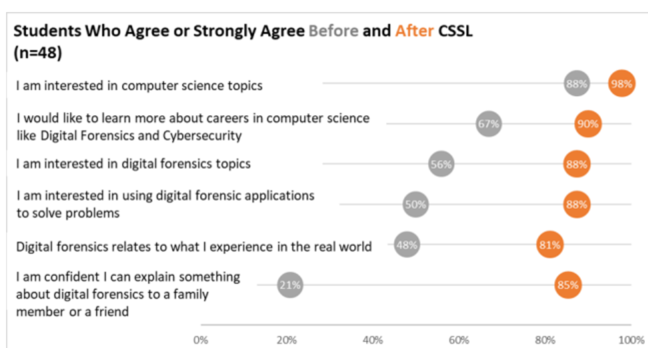
Research Questions:

How effective is the Investigate and Decide learning environment implemented in DFSLE for; 1. Inspiring young women and other underrepresented youth to pursue careers in DFIR and CS? 2.Teaching digital forensic knowledge, skills, and abilities that are directly applicable in the workplace. 3. Increasing interest in digital forensics and cybersecurity in specific, and computer science education in general, and related technical skill development by exploring the complex issues associated with cybercrime? 4. Attracting participants to STEM learning through real-world investigative scenarios and by interaction with role models in the industry?

Key Findings - 2018 Pilot Program:

"Overall, students enjoyed the program and understood how to use the digital platform. Students especially enjoyed acting like "detectives", learning about and independently going through the process of using digital forensics tools to recover data. Students also enjoyed that the skills they learned could help solve problems in their everyday life."

Excerpt from EDC Evaluation Report



Pilot Sites: CODEWORKS/Baltimore City Schools/U.B., Baltimore, Maryland * GNO STEM CAMP, New Orleans, Louisiana * WANIC (Career & Technical Education Summer Program) Everett School System, Washington State

The Cyber Sleuth Science Lab is a project of Digital Forensics Solutions made possible by the National Science Foundation. This material is based upon work supported by the National Science Foundation under Grant No. 1640107. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

STEM+C: Integrating AI Ethics into Robotics Learning Experiences

DRL #1934151

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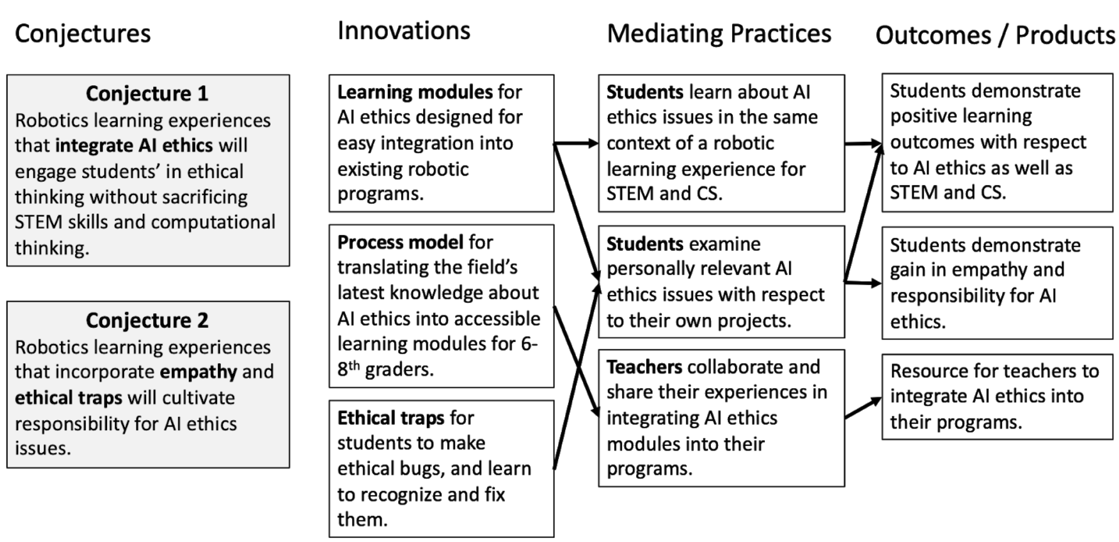
University of Colorado Boulder

Motivation: Artificial intelligence (AI) systems, tools, and techniques are being rapidly adopted and used in devices and products that youth interact with on a daily basis at home and in schools. Educators are starting to recognize the need to teach K-12 students about AI and are developing novel programs, such as robotics, to address this need. However, AI ethics, despite its critical importance in youth's future personal, civic, and work lives, has been largely neglected.

Goals: This project develops and integrates AI ethics teaching modules into existing robotics youth programs. As students learn about robotics, they will also learn about emerging ethical issues in AI in the design of robots at the same time, including fairness, transparency, autonomy, respect, accountability, privacy, and security. Also, the project promotes responsibility for AI ethics and skills among students.

Approach: This project uses two innovative interventions by engaging learners in (1) stories based on AI ethics issues that are likely to be meaningful to young adolescents, such as surveillance of their physical activities, and (2) empathy driven hands-on activities with an embedded ethical dilemma in which students will experience the process of committing an ethical error, identifying the error, and fixing the error, potentially developing a stronger sense of ownership of ethical issues and agency to address them.

Outcomes: The research will contribute to the understanding of the effects of integrating AI ethics into STEM programs such as robotics for students, particularly regarding their engagement in, awareness of, knowledge about, and sense of responsibility for a range of emerging ethical issues underlying the use of AI in STEM and CS fields. It will provide a new model for teaching AI to students integrated with STEM concepts in a contextualized and relevant manner, by elevating ethics as a primary concern, as opposed to as a side issue.



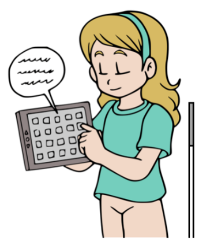
tScratch: Tangible Programming Environment Targeted for Students who are Blind or Visually Impaired (BVIs)

Award Number: 1742242

PIs: Dianne Pawluk, Giovanni Fusco (co-PI)
Institutions: Virginia Commonwealth University, The Smith Kettlewell Eye Research Institute
Contact e-mails: dtpawluk@vcu.edu, giofusco@ski.org

Need

- Provide resources for BVIs to learn computer programming alongside their sighted peers
- Lower hurdles for BVIs to learn programming without raising hurdles for sighted students
- Increase engagement for BVIs in learning programming while keeping engagement for their sighted peers.



Increase number of students who are blind or visually impaired considering STEM careers

Team

- Virginia Commonwealth University (Dr. D. Pawluk, B. Goolsby, H.W. Kim)
- The Smith Kettlewell Eye Research Institute (Dr. G. Fusco, C. Pitcher-Cooper)
- San Francisco State University (Dr. T. Siu)
- Evaluators: Praxis Associates (Dr. Y. Susskind, Dr. J. Susskind)
- Consultant: S. O'Modhrain (University of Michigan)

Collaboration

- The team welcomes the involvement of teachers of grades 8-12, teachers for the visually impaired and both adults and older children who are BVI.

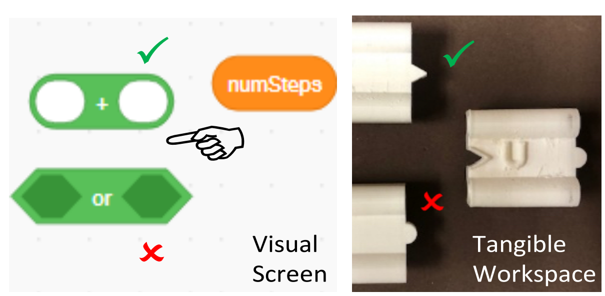
Goals

For both BVI students and sighted students learning together: improve their...

- ability to apply programming concepts
- ability to share in teamwork
- perspective of working with BVI students
- interest in computing science/STEM
- view of the ability to have a career in computing science/STEM
- view of inclusion in the education community

Approach

- develop a tangible + audio interface to the Scratch programming environment, usable by BVI students alone or as part of a team
- develop tangible coding tiles that allow for moderate program complexity and with similar hurdle lowering features as Scratch
- develop a tangible organizational structure with audio guidance to navigate code development and debugging
- develop instructional material to allow teaching of BVIs and sighted students together



Project Title: Collaborative Research: The Development of Computational Literacy through the Integration of Computational Thinking and Early Language and Literacy Development in Urban Preschools
Award Number: 1814039
PIs: Jillian Orr (WGBH), Heather Lavigne (EDC)
Contact email(s): jillian_orr@wgbh.org; hlavigne@edc.org

Overview
WGBH (a leading producer of educational STEM media) and EDC (experts in how technology can influence and enhance teaching and learning) are collaborating on an **Exploratory project** entitled ***The Development of Computational Literacy through the Integration of Computational Thinking and Early Language and Literacy Development in Urban Preschools***. Building on the current interest in helping young children—especially those from underserved backgrounds—to think computationally, the EDC research and WGBH development teams are conducting **an exploratory research process** to understand: **(1)** how preschool children (ages 4 - 5.11 years old) apply computational thinking (CT) while developing their narrative skills (storytelling and understanding the structure of stories); **(2)** how preschool children and their teachers make meaning of experiences that are designed to foster computational thinking while composing narratives; and **(3)** what evidence of promise exists for a new learning intervention (called *The Story Emporium* and consisting of a touch-screen digital platform that children can use to program their own stories, along with accompanying hands-on activities and teacher scaffolds) in supporting computational literacy (children's proficient use of CT to solve their own challenges) and narrative competence.

To this end, WGBH and EDC are collaborating on a co-design process with preschool teachers, children, and field experts. Modeled on Clements' (2007) **Curriculum Research Framework** (CRF), project activities include: **(1)** developing a model of the project's pedagogical foundation, informed by discussions with experts and a review of literature; **(2)** conducting exploratory research to investigate the opportunities to integrate CT and narrative development through interviews with preschool educators and storybook tasks with children; **(3)** revising the model of the project's pedagogical foundation based on findings from the exploratory research and conversations with experts at an in-person forum; **(4)** developing computational literacy (CL) learning tasks and conducting formative research on children's CL and teachers' instructional practices while iteratively developing and testing a learning intervention (*The Story Emporium*); **(5)** revising prototypes and continuing development of CL learning tasks, and; **(6)** conducting a pilot study to investigate the promise of the intervention in cultivating preschoolers' CL and narrative competence.

Intellectual Merit
Despite increasing calls to integrate CT into early childhood education, **very little is known about preschool children's CT learning and teachers' CT understanding towards the development of computational literacy**. Major contributions of the project include building broader knowledge about integrating CT with narrative development and about how children build and teachers support computational literacy as they engage with curricular resources that capitalize on the unique affordances of technology. Major contributions also include the development of a set of computational literacy learning tasks that could be used by researchers to measure young children's CT abilities.

Broader Impacts
Policy makers and education leaders have recognized the need not only for more students to enter the field of computer science but also for young people in general to have a greater understanding of how computers and other technologies work, how they are designed, and the logical processes upon which computing is based (Guzdial, 2008; NRC, 2012). Computational thinking skills were identified as one of the key characteristics of future work environments, in which human interactions both shape and are shaped by technology (Malyn-Smith, Blustein, Pillai, Parker, Gutowski, Diamonti, 2017). Introducing well-designed, developmentally appropriate CT experiences early will ultimately increase the number and diversity of children who are computationally literate and who may develop an interest in computing throughout the course of their education. By exposing more preschool teachers to professional learning focused on integrating CT and providing supports to encourage successful implementation, the project will also increase the diversity of the educators involved in the discourse about teaching and learning practices to support computational literacy. In the future, the curricular resources could be further developed and nationally disseminated, thereby helping to set the standard for high-quality, research-based approaches to preschool computational literacy.

The Evaluation of a Model Spatial Thinking Curriculum for Building Computational Skills in Elementary Grades K-5

Grant Number DRL 1543204

Principal Investigators: Steven Moore, Ph.D. and Gary Scott, Ed.D.

Institution: University of Redlands

Contact: steven_moore@redlands.edu

Website: https://sites.redlands.edu/spatial-stem-c/

STEM for All Video: https://stemforall2018.videohall.com/presentations/1082

Background

Initiated in November, 2015, the Evaluation of a Model Spatial Thinking Curriculum for Building Computational Skills in Elementary Grades K-5 (Spatial STEM+C) project, evaluated strategies for building visuospatial and computational skills in elementary-aged children that underlie success in later gatekeeping STEM courses.

Project Goals

The goals of the project were to (1) document relationships among spatial thinking abilities, computational thinking skills, and mathematical performance in K-5 children; (2) evaluate the effectiveness of hands-on activities designed to build spatial thinking abilities in K-5 students; and (3) evaluate the impact of spatial thinking training on computational thinking ability and mathematical performance.

Study Sites

Pilot testing took place at Lugonia Elementary School in Redlands, California, and Inland Leaders Charter School (ILCS) in Yucaipa, California during Spring, 2016. A comparison-group study was conducted during the 2016-17 school year at ILCS.

Comparison-Group Design

Two treatment classrooms in each K-5 grade at Inland Leaders Charter School in Yucaipa, California, implemented spatial thinking activities for approximately 30 minutes each week during a school year; two control classrooms in each grade did not do the designated activities. The spatial activities included creating designs with manipulatives, mapping classrooms and schoolyards, using a map to find treasures, and providing directions with coordinate systems. At the beginning and end of the school year, all students completed spatial and mathematics assessments. A spatial-computational thinking assessment was also piloted with K-2 students.

Analysis

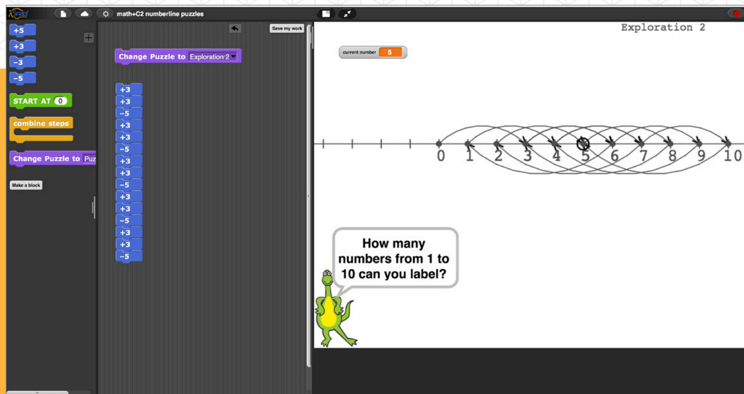
With each spatial skill as an outcome, several mixed models were conducted, and Type III sums of squares were calculated to find omnibus effects. Fixed effects included time, group (treatment vs. control), grade (centered at the middle grade if applicable), gender, and a time by group interaction as fixed factors. A random classroom effect was also included.

The project evaluators also acquired qualitative data through focus groups with the teachers. Information sought from teachers included feedback on spatial thinking activities, spatial thinking assessments, and computational thinking assessments, and the teachers' perceived outcomes for spatial, computational, and mathematics abilities.

Conclusions

The project reported the following conclusions: (1) Spatial abilities were moderately to highly correlated with computational thinking abilities and mathematical performance; (2) Embodied spatial activities with embedded spatial language can build spatial thinking skills: (3) Targeting individual students who need help with spatial skills may be more effective that targeting demographic categories of students; (4) Assessments are needed that better measure targeted components of spatial thinking skills and computational abilities being developed by K-5 children in their play and academic activities; (5) Helping parents, teachers, and other caregivers to engage in supportive, joint spatial problem-solving with children may be effective in building spatial skills in young children; and (6) Assessments are needed that better measure targeted components of spatial thinking skills and computational abilities being developed by K-5 children in their play and academic activities.

Think Math+C: Integrating Programming into a Comprehensive K-5 Mathematics Curriculum



PIs: E. Paul Goldenberg, June Mark, Deborah Spencer, Kristen E. Reed

October 2017-September 2020

Education Development Center (EDC)

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www.edc.org

Description and Goals

Think Math+C integrates computer science into young children's mathematics experience in a way that is natural, developmentally appropriate, embedded in mathematics content, and supportive of the mathematics. It presents computer programming as a language for students to express their mathematical ideas and use computational thinking.

Where mathematical notation on paper is static—correct or incorrect—a program is active, and students can see its effects in real time. This process can be transformative in a mathematics classroom. Acts such as decomposing problems and generalizing from specific instances become more visible, thereby enabling students to examine and debug their own thinking.

National Science Foundation
Grant No. 1741792.

Activities and Outcomes

- Develop a scope and sequence for a K–5 mathematics curriculum that builds a coherent progression of programming ideas and skills naturally across the elementary grades
- Design and implement four modules in grade 2 that integrate programming into the critical grade-level mathematics
- Examine the effects of the integrated modules in comparison to classrooms not using programming as a medium for exploring mathematical ideas
- Pilot and refine measures to capture children's mathematical and computational thinking

Currently, we are piloting and refining the integrated grade 2 modules, administering classroom observation and child cognitive interview measures, and refining the K–5 scope and sequence.

A newly awarded NSF grant, *Math+C: Mathematics through Programming in the Elementary Grades*, will allow us to extend this work in grades 3 through 5.

VELA: Dynamic Activities for Middle School Programmers

PIs: Shuchi Grover[2] | Patrik Lundh[1] | Nicholas Jackiw[1]
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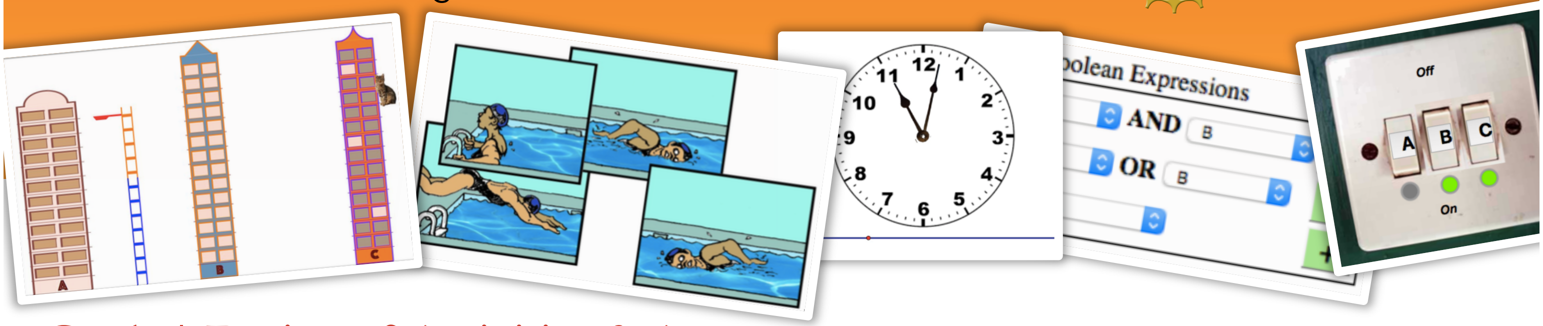
DRL-1543062



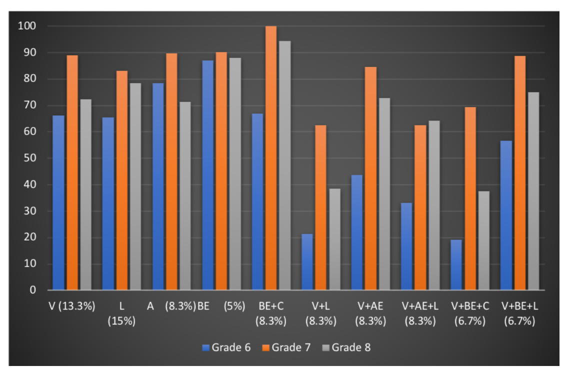
Goals | Design of Activities & Assessments

- **V**ariables, **E**xpressions, **L**oops & **A**bstraction are key foundational concepts of programming necessary for learning computer science as well as (computational) modeling in Science and Mathematics
- With the goal of helping students—regardless of gender, prior math preparation or socio-economic status (SES), learn these concepts well—our research explored the potential use of interactive non-programming activities that drew on pedagogic inspiration from research and use of *dynamic mathematics representations*
- 4 digital and 2 unplugged activities designed and tested. ***Available** at* http://csforall.sri.com
- A summative assessment targeting these concepts designed and validated. ***Available at*** http://edfinity.com

Research & Results

- Results of exploratory research show promise of VELA work.
- Empirical studies with 3 teachers in 6th, 7th, 8th classrooms in a diverse, urban school district showed statistically significant pre-to-post gains for all classrooms.
- Learning gains were not significantly different by gender or prior math/English scores, or grade. *All students learned!*
- Students performed statistically better on open-ended projects than quasi-experimental control group from same district.

School Characteristics	Gr. 6	Gr. 7	Gr. 8
Low SES	85%	40%	87%
Math Proficiency	55%	79%	34%
English Proficiency	54%	80%	41%
Science Proficiency	62%	84%	34%
Learning Disabilities	12.8%	3.5%	15%



Dissemination & Impact

- Openly accessible activities & lesson plans (*http://csforall.sri.com*)
- Journal publications, conference presentations, webinars
- VELA activities have been incorporated in curricula at large urban, diverse districts like San Francisco Unified School District serving tens of thousands of middle school students.
- Our journal publications and open access activities have also been picked up by educators outside the US as well (such as the Computing At School efforts in the UK).
- Video at NSF Stemforall VideoHall (2017) showcase (winner of Facilitators' and Presenters' Awards)
- Webinar (July 2019) to share our designed middle school assessment hosted by CSForAll teachers
- **Key Publications:**

Grover, S., Jackiw, N., & Lundh, P. (2019). Concepts before coding: non-programming interactives to advance learning of introductory programming concepts in middle school. *Computer Science Education*, *29*(2-3), 106-135.

Grover, S. (2019). An Assessment for Introductory Programming Concepts in Middle School Computer Science. In Proceedings of the *2019 Annual Meeting of the National Council on Measurement in Education (NCME),*

https://stemforall2017.videohall.com/presentations/872

Award # 1542971- Bridges to CS4ALL: Advancing High School Computer Science through Math and Science Integration

PI: Lucia Dettori DePaul University, ldettori@depaul.edu
co-PIs Steven McGee (The Learning Partnership), **Andrew Rasmussen** (Chicago Public Schools)

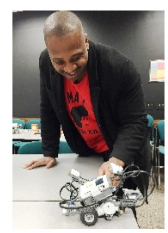
Goals

- Integration of computational thinking and CS concepts units into STEM subjects
- Professional development for math & science teachers on how to integrate CS units in their courses
- Development of a teacher leadership program to create professional learning communities within schools and become agents of cultural change around CS
- Assessment of students' computational thinking learning and preparation for taking ECS

Activities

- Deliver CS professional development workshops for math and science teachers.
- Coordinate research and implementation efforts with CPS high school network chiefs.
- Develop instruments to evaluate the impact of the integration of computational thinking in math and science.



Where are we now?

- Delivered professional development workshops to 38 math teachers on Bootstrap:Algebra to support integration of computational thinking.
- Provided professional development for 11 biology teachers to develop skills in using SageModeler to support computational thinking.
- Developed curricular support materials for science teachers to support integration of SageModeler.
- Worked with 4 high school network chiefs on support for implementation and research efforts of the Bridges project.

Understanding How Integrated Computational Thinking, Engineering Design, and Mathematics Can Help Students Solve Scientific and Technical Problems in Career Technical Education **(INITIATE)**
Award- 1741784
8/19/2019

PI: Jared Oluoch, The University of Toledo, Jared.oluoch@utoledo.edu; CoPIs Ahmad Javaid and Charlene Czerniak, Ahmad.Javaid@UToledo.Edu, Charlene.Czerniak@utoledo.edu
Website: http://www.utoledo.edu/research/initiate/
2018 STEM FOR ALL VIDEO SHOWCASE: https://stemforall2018.videohall.com/presentations/1099

Overview. INITIATE is a 3-year, STEM+C Partnership Program Design and Development project that partners high school Mathematics and Career Technical Education (CTE) teachers in Toledo Public Schools (TPS). Due to mathematics oftentimes serving as a gatekeeper for further STEM study, including technical careers, and to the strong reciprocal relationship between mathematics, computational thinking, and preparation for STEM careers, the project includes teachers of Algebra I, Geometry, Algebra II, and Statistics/Analysis. The topic of smart vehicles coupled with project-based learning (PBL) will effectively blend mathematics with science (e.g., physics), technology, and engineering. This report describes the major activities during the project time period ranging from September 15, 2018 through August 2019.

Project Goal. The overarching goal of the INITIATE program is to create and test a teacher professional development intervention that encourages teachers to integrate computational approaches into their teaching. By the conclusion of the 3-year project, we expect to provide professional development to 36 mathematics and career technology education teachers.
Six objectives have been identified that will help reach the overall goal of INITIATE:

1) Increase the number of students who pass Algebra I, Geometry, and Algebra II courses and high school Ohio mathematics tests,
2) Improve student computational thinking skills (Data Practices; Modeling & Simulation Practices; Computational Problem-Solving Practices; and Systems Thinking Practices),
3) Increase student interest in STEM and STEM-related topics, courses (e.g., 12th grade elective Statistics and Analysis), and career paths,
4) Increase CTE teacher understanding of state mathematics standards,
5) Infuse project-based learning strategies into mathematics teaching, and
6) Increase mathematics and CTE teachers' ability to work together to improve the mathematics and CTE curriculum.

Research and Education Findings
Overview: During year 2 the INTIATE grant implemented the program's first round of academic year meetings with cohort 1 and the second Summer Institute with cohort 2.

Summer Institute: Data were collected by evaluators and reviewed by the INTIATE team to determine if goals for the summer institute were achieved in 2018. These findings were used to revise the summer institute for 2019. Data collected by a teacher computational thinking assessment from 2018 summer institute were analyzed and the Wilcoxon signed-rank test showed that the 2-week summer institute in 2018 led to statistically significant gains in teacher knowledge of computational thinking ($Z = -1.992$, $p = .046$). Results from the teacher concern survey given before and after the 2018 summer institute indicated that before the summer institute teachers were interested in the INITIATE model but were not quite sure it was relevant to their teaching. After the summer institute teachers were still not certain how the INITIATE model would fit into their teaching. However, they understood enough about the model to begin to ponder exactly how it might be managed in their classrooms. Based on these findings the 2019 summer institute was revised and improved to meet the goals stated above.

SchoolWide Labs: Supporting the Integration of Computational Thinking into Middle School Science through Curriculum and Professional Development

NSF Grant #1742053, 1742046

Tamara Sumner, University of Colorado Boulder, sumner@colorado.edu, PI
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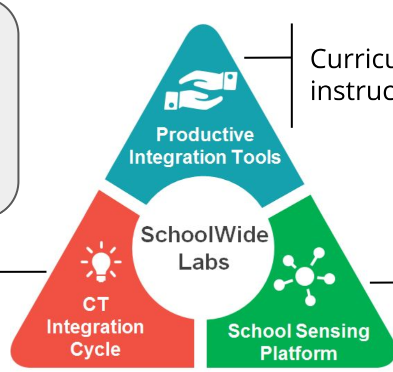
https://www.colorado.edu/program/inquiryhub/curricula/maglev-trains-schoolwide-labs

Goals

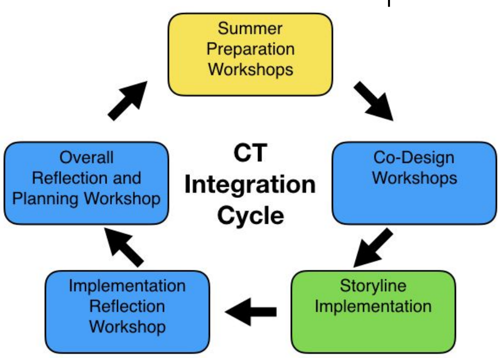
~ Integrate CT activities into required science and STEM classes
~ Support Teachers to implement CT activities

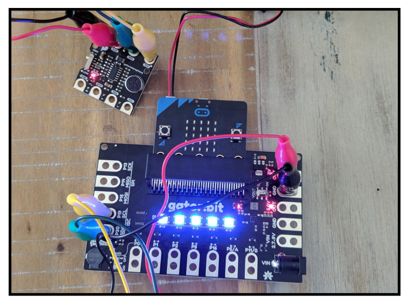


Curricular storyline units & other instructional resources

Programmable sensor technologies that allow students to collect and display data.

Professional development to collaboratively design model curricula, and activities for students to use in science classrooms.





Results

~ Increased student engagement and relevance of curriculum
~ Teachers increased ownership of curriculum development & interest in using sensors in more units

Products

~ Maglev Train Storyline (**available now!**)
~ Mold Growth Storyline (coming soon)
~ Sensor Immersion Storyline (coming soon)
~ Intro to Sensors and Data Displays For Teachers (coming soon)

Impact

The project has engaged 650 diverse 5-8 grade students in CT (>77% from nondominant backgrounds) from 5 public schools.

Team

CU Boulder, Utah State University, Denver Public Schools (teachers and science/STEM administrators), SparkFun Electronics

UtahState University

DENVER PUBLIC SCHOOLS
Discover a World of Opportunity™

sparkfun ELECTRONICS

CALC: Using Collective Argumentation to Develop Teaching Practices Integrating Coding Within Science and Math Curriculum (Grades 3-5)

(NSF Grant# 1741910)

Principal Investigator: Timothy L. Foutz, Ph.D., PE
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2019 NSF Video Showcase: https://stemforall2019.videohall.com/presentations/1500

Co-Principal Investigators
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- Annamarie Conner, Ph.D.; Mathematics Education
- Roger B. Hill, Ph.D. Career and Information Studies
- Sidney A. Thompson, Ph.D.; Engineering

Penn State University • ChanMin Kim, Ph.D.; Learning Design, Technology, Educational Psychology
Partnering School District: Jackson County, GA

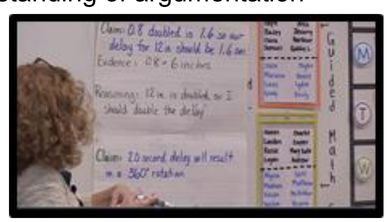
The **CALC** approach is innovative in that teachers will use robust teaching methods currently used to teach mathematics and science in their teaching of coding. **CALC** supports the learning of coding by providing teachers with a formal, structured means to

- trace the growth of students' understanding, and misunderstanding of coding as they form their ideas,
- facilitate students' use of evidence, not opinion, to select their coding structure, and
- help each student realize she/he, as well as others, is a legitimate participant in developing code.

Objectives of the **CALC** approach are to

- Increase the learning of *how to code* in the elementary curriculum given that teachers will know how to integrate mathematics and science pedagogy into the teaching of coding through argumentation,
- Emphasize the argumentation approach as an integrator for the teaching and learning of coding, mathematics, and science, and
- Direct students away from informal methods to develop code to the more formal, structured approach recommended for novice programmers.

Activities associated with this **CALC** project will enhance teachers' understanding of argumentation using the **CALC** concept and then investigate how implementing that understanding helps students learn how to code.



Example using the Georgia 4th grade Math Standard: *understand fraction decimal notation and compare decimal fractions* Lesson: Code the motor so your robot travels 6 in. then make your robot travel 18 in.

Research Findings to date

- Findings suggest that teachers understood the **CALC** approach and coding content. Some had difficulties transferring their new knowledge to new robotic platform.
- Teachers who were less confident of their coding knowledge indicated a desire to have the CALC approach to be explicitly presented in modules. Teachers who were more confident of their coding knowledge desired general instruction of the **CALC** approach.
- The set of teachers enrolled in this **CALC** course had varying levels of prior knowledge related to coding and argumentation. Some teachers had completed workshops focused on educational robots. Some teachers had never coded or had little exposure to coding. This diverse background knowledge created a challenge to provide out-of-the-classroom support that was useful to the whole class. It is noted that the teachers were pleased with this unique experience. Overall, the CALC concept was well-received.
- Many teachers were "stressed" to keep up with the lessons. The teachers maintained regular classroom responsibilities while enrolled in the CALC course. This course was taught as a typical evening course offered to full-time graduate students.

This material is based upon work supported by the National Science Foundation under Grant # 1741910*. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

Workshop to Develop an Interdisciplinary Framework for Integrating Computational Thinking in K-12 Science, Mathematics, Technology, and Engineering Education

Award# 1647018

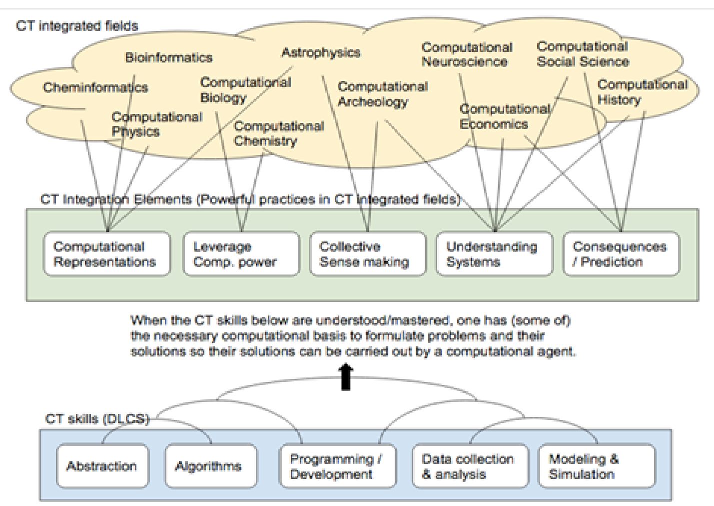
2017-2019

Education Develoment Center

Principal Investigator: Joyce Malyn-Smith, Co-Pi: Sarita Pillai

Project Overview:

NSF funded CT researchers and practitioners exploring CT in K-12 developed a Framework for Computational Thinking from a Disciplinary Perspective aimed at discovering how CT can be encouraged, taught and practiced within disciplines throughout primary and secondary education. The resulting Framework identified an initial set of "elements" describing what CT practices bridge learning and working in highly sophisticated STEM environments and provided examples of these practices used by STEM professionals at work and developed by students in schools. Evidence was found that K-12 subject area teachers were integrating CT in ways that were consistent with its use in CT-integrated fields. The following five Elements of CT Integration from a Disciplinary Perspective that emerged from the reviews and discussions were:



- Understand (complex) systems.
- Innovate with computational representations.
- Design solutions that leverage computational power/resources.
- Engage in collective sense making around data.
- Understand potential consequences of actions.

Outcomes:

- Framework
- Dedicated issue of the Journal of Science Education and Technology titled: Computational Thinking from a Disciplinary Perspective: Integrating Computational Thinking in K-12 Science, Mathematics, Technology, and Engineering Education to be published in 2020.
- Publication: Malyn-Smith, J., Lee, I., Martin, F. G., Grover, S., Evans, M. A., & Pillai, S. (2018). Developing a Framework for Computational Thinking from a Disciplinary Perspective. CTE 2018 conference proceedings, pp. 182-186.

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EDC Education Development Center

Writing Data Stories:

Integrating Computational Data Investigations into the Middle School Science Curriculum

Award DRL-1900606

Project Team

PI: Michelle Wilkerson, *Univ. of California, Berkeley* (mwilkers@berkeley.edu)
CoPIs: Kris Gutiérrez, *University of California, Berkeley*
William Finzer, *Concord Consortium*
Hollylynne Lee, *North Carolina State University*
Evaluators: Anthony Petrosino, *Univ. of Texas, Austin;* Lina Haldar, *Haldar Consulting*
Partners: Teachers and Advisers from Unified School Districts of Pittsburg, Oakland, Bonsall, and El Cajon Valley, California

Project Overview

Writing Data Stories seeks to reorganize how linguistically and ethnoracially minoritized students in California middle schools learn about and interact with data. The project will engage middle school students in exploring scientific datasets about earth and the environment using flexible online data visualization and analysis tools. Typically, school data investigations use small datasets that students create themselves, or larger datasets that clearly illustrate simple relationships and are less connected to students' lives. Our goal is instead for students to author "data stories" using CODAP, an online data visualization and manipulation tool, to expore locally relevant, publicly available datasets and position the issues they care about at the center of each investigation.

At the core of this reorganization is a *syncretic* approach where students deeply study everyday and scientific ways of knowing or doing that are traditionally in tension. This approach was developed specifically to support learners from nondominant backgrounds, including students identified as Dual Language Learners. It brings together experience and data by focusing on everyday argumentation, advertising, and data-based scientific texts as genres. This invites students to put their personal narratives and experiences and public scientific datasets into direct conversation, inviting students more authentically into the practices of science as they learn them.

Goals and Objectives

Writing Data Stories is in its first of three years. We are working with a small group of partner teachers at one school to enact curriculum, software, and professional learning supports. In Years 2 and 3, we will expand to serve up to 30 classrooms, 60 teachers, begin quantitative data collection, and share our curriculum and support materials.

STEM+C Computing is a program of the Division of Research on Learning in Formal and Informal Settings, Directorate for Education and Human Resources, National Science Foundation, 2415 Eisenhower Avenue, Alexandria, VA 22314