STEM+C: Building Educational Bridges between Computer Science and Biology through Transdisciplinary Teamwork and Modular Curriculum Design

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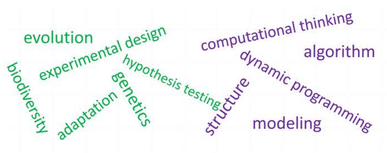
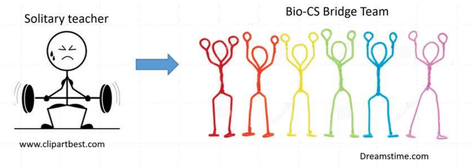
STEM+C: What is the need?

- Need for **fundamental change** in the teaching of biology in order to emphasize learning **of core concepts** rather than memorizing large numbers of facts
- To learn to solve today's complex problems, students should engage with **scientific practices**, including the process and interdisciplinary nature of scientific discovery, communication and collaboration, **quantitative data interpretation, and experience with modeling, simulation, and systems** approaches to biology – in short, **computational thinking and approaches**
- To address this need, new standards for high school instruction require **integrating** scientific practices with computational thinking: STEM + C curriculum
- BUT…. it is difficult for educators to design and implement STEM+C curricula because they often have little understanding of the **terminology, key concepts, tools and approaches** that each side has to offer



The Bio-CS Bridge Project

- We propose that fostering **transdisciplinary teams** among STEM and computer science educators and students at multiple levels (high school, post-secondary) is critical for developing highly effective STEM+C integrated curriculum



- Curriculum must be highly **modular** to allow for integration in both Biology and CS classes, at levels from freshman intro to senior AP
- Students are most engaged when they are involved in solving **real-world problems** they perceive to be important

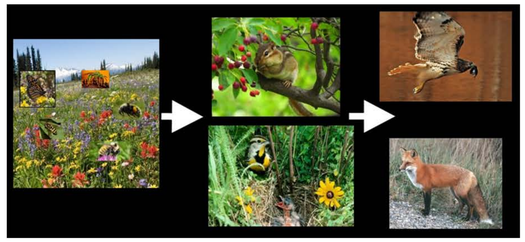
Research Questions

- **The need**: Integrating biological practices and computing approaches to teach students how to address real-world problems
- **Our vision**: Transdisciplinary teams to build a modular curriculum
- **Research Question 1**: Is developing a transdisciplinary, vertically integrated team comprised of biologists, computer scientists and education specialists a transformative precursor for the generation of effective computational tools and STEM+C curriculum?
- **Research Question 2**: Will modular curriculum incorporating computing and computational thinking into scientific practices allow teachers to effectively deliver classroom content to students at multiple levels in biology and computer science?

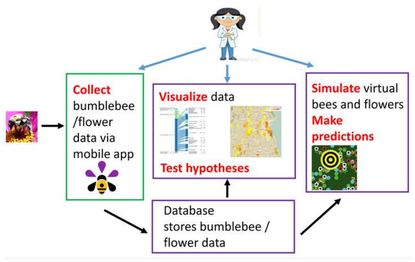
The Bio-CS Bridge approach

- Students engage in scientific practices using **biological data that they collect themselves**
- Students **design and implement computational tools** to gather and analyze data
- Students address a complex **biological problem**: our example is pollinator decline and loss of biodiversity
- **The strategy is generalizable**, and can be modified to address other biological questions, and even other STEM fields

The motivating biological problem: Pollinator decline



- **Pollinator diversity is critical** to ecological resilience: plant-pollinator interactions provide food and habitat for many species
- **Pollinators are declining in biodiversity** and geographic distribution, likely due to many causes: pesticides, habitat loss, disease, invasive plant species
- **Data are needed** on current distribution of pollinators, in particular native bumblebee species, and interactions with plant species
- **Analysis of these data needed** to determine and mitigate factors important in decline
- **Understanding the use of computational thinking and approaches to this important problem** will motivate students and prepare them to address other important societal problems

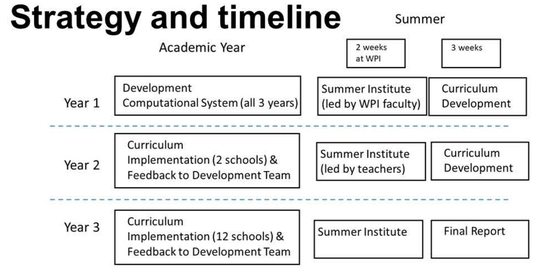


- Students **use** provided software tools to **address a biological problem**: gather field data on bee-flower interactions for the database
- Students **design** software tools to approach the biological problem: **build** upon provided software, develop new simulations, apps, webpages
- Students **analyze** data from their field studies, the database, or the simulation: develop **hypotheses** and make **predictions**

Creating a TransdisciplinaryTeam

- **The Transdisciplinary (TD) Team:**
  - WPI faculty: 1 Bioinformatics, 1 Biology, 1 Computer Science, 1 Education
  - High School Teachers: 2 Biology, 2 Computer Science; 10 teacher integrators to be recruited for years 2 and 3
  - Graduate Students: 2 Bioinformatics, 1 Computer Science
  - Undergraduate Students: 1 Bioinformatics, 5 Computer Science
  - High School Students: 1 Computer Science
- **The entire TD Team** met four times during the academic year (3 hours / meeting) and will meet for 2 weeks in the summer
- **The software development team**, led by Ruiz, Gegear, and Ryder and including all of the students, met weekly throughout the academic year and developed a suite of software tools (please see our Digital Arcade poster!)

Strategy and timeline



- **Teacher leaders** are an essential component of the TD team throughout the project – both during academic year and summers
- **Summer Workshops**
  - Train teachers in the Bio-CS Approach, and the use and design of software tools
  - Taught by faculty first time; teacher leaders later train teacher integrators
- **Teacher leaders develop curriculum** later in the summer with support of the TD team
- **All teachers implement curriculum** during academic years 2 & 3

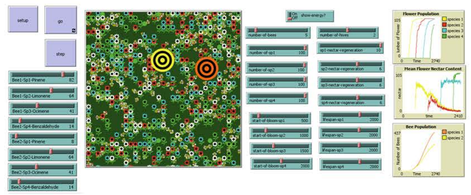
TD Team meeting topics

- **Brainstorms:** getting on the same page
  - What is needed for a transdisciplinary team to succeed?
    - Communication / Mutual respect / Open-mindedness
  - What is computational thinking?
    - Abstraction / logic / strategies / tools / pattern finding / data analysis / prediction
- **Learning teachers' needs**
  - Curriculum standards
  - Content of classes – *replacing*, NOT *adding* more material
- **Teachers learning to use and design simulations**
- Group discussion / refinement over several sessions: **What should a curriculum module look like?**
- **From our evaluator: '**The team members draw from the knowledge of each discipline and representative to solve problems as they move forward in the development process.'

Creating Modular Curriculum

What should a curriculum module look like? An illustration using our Simulation Component

- Module must **integrate** biology and computer science
- **'Create your own adventure'** – basic module has both biology and computer science resources to allow multiple uses
  - Can be **tailored** to either a biology or a computer science lesson, and taught by either biology or computer science teachers
  - Can be used at **many different levels** in the curriculum
  - Can be shorter or longer based on teacher needs



- **Module**: Simulation of bees in a floral environment
- **Plug and Play: Using the simulation** to test hypotheses in a biology classroom
  - Example Hypothesis: Invasive floral species will disrupt the ecosystem balance and lead to the loss of native bumblebee species
  - Use the simulation to create this scenario (by adjusting sliders)
  - Generate data for analysis
- **Design: Building a simulation** in either a biology or a computer science classroom
  - Agent-based modeling:
  - Each type of 'agent' (e.g., bees, flowers) follows 'rules' based on biology
  - Starlogo: a simple block-based language for beginners
  - Netlogo: a more powerful text-based language for intermediate students
  - Modular structure: can start from scratch, or add modules to a 'starter sim'
  - Designing the simulation based on the biology
- **Resources**
  - Starter simulation, additional modules, complete simulation, all developed by WPI students
  - Biology background info on pollinator decline
  - Computer science background info; tutorials for both programming languages
  - Lesson plan developed by teachers

Accomplishments in our first 9 months

- TD Team creation & development
- Suite of software tools designed and implemented (please see our Digital Arcade poster!)
- Teacher training & feedback on simulation tools
- Agreement on initial module ideas for the curriculum

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