Interdisciplinary Materials for High School Classrooms:
Mathematics, Science, Computing

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Modules: A Chronological View

- 2005 Cross disciplinary Mathematics and Biology High School Teacher Workshop and construction of first modules.
- 2006 BioMath Connection (BMC) was funded by NSF for five years to develop 15 high school week-long modules and hold three one week workshops to help teachers test the new modules.

Modules: A Chronological View

- 2010 Integrating Mathematics and Biology (IMB) project is funded by NSF for four years to create five more biomath modules, and one semester or whole year courses for 12^{th} grade mathematics or science courses or combined courses. Partner schools across the country play a key part.
- North Dakota has already gained approval to offer a full year BioMath course starting next year.

Modules: A Chronological View

- 2010 The Value of Computational Thinking Across Grade Levels (VCTAL) project is funded to develop 12 week-long modules for high school classes across all disciplines and grade levels. This project includes partner schools and their teachers, and also Summer Student Prototyping Workshops to provide advice to writers and teachers, and test the materials on students.

Project Partners

- Rutgers University
- Boston University
- Hobart and William Smith Colleges
- Consortium for Mathematics and Its Applications (COMAP)
- Colorado State University
- Computer Science Teachers Association (CSTA)
- Partner high schools and teachers

Project Ingredients

- Module Development
- Module Testing
- Evaluation & Research
- Student Engagement
- Teacher Engagement
- Partner Schools
- Dissemination

Bio-Math Modules

Bio-Math: Over-Arching Goals

- Teaching math and biology together as inherently interdisciplinary subjects for the enrichment of both
  - Biology is increasingly seen as an information science with rich opportunity for use of mathematics
    - Gene sequencing, food webs, genetic testing, etc.
  - Biology themes highlight the relevance of math
  - Mathematical treatment allows introduction of important topics in modern biology
    - Computational biology; genomics; neuroscience
  - Bio-math may offer an alternative to calculus in 12th grade

Bio-Math: Challenges

- Author teams need: math content expertise, biology content expertise, and pedagogy expertise
- Works best if: biology teachers and math teachers work together
- Need topics that provide math content and biology content at an appropriate level
- Need to address standards in both fields

Bio-Math Example: Imperfect Testing

Content: genes, genetic testing and variation, mutations, probabilities including Bayes Rule, pharmacology, and decision making based on data for grades 10-12

Case study approach:

- An adult female learns she has a positive mammogram. What does that mean?
- She also has the genetic test and discovers she has the BRCA gene. What does that mean?

Medical and Mathematical background

Bio-Math Example: CrIME – Criminal Investigation through Mathematical Examination

Content: biological identification & behavior patterns within a species, skin layers (epidermis, dermis, hypodermis), coordinate systems, graph theory, linear algebra, and fingerprint analysis based on data for grades 10-12

Discovery approach:

- A crime has been committed. Fingerprint evidence is collected for examination.
- Students are guided through process of developing a fingerprint identification system.
- The system is used to analyze fingerprint evidence to eliminate/identify likely suspects.

Forensics and Mathematical background

Creating a 12^{th} Grade Course

- One semester or two semester courses:
  - Sequencing modules from a mathematics development view for predominantly math classes, and sequencing modules from a biological point of view for use in biology classes
  - Amount of background material needed in each module for sequencing
  - Challenges of getting course approval in states, e.g. North Dakota

Computational Thinking Modules

Computational Thinking: Immediate Goal

- Help to define "Computational Thinking"
  - What is it?
  - Who should think computationally?
  - How does this differ from "mathematical thinking" (or just "thinking")?
  - Where is its place in HS curricula?

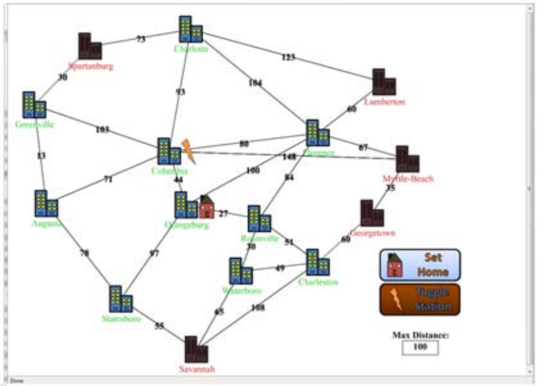
Toward Defining CT

- CSTA/ISTE definition says CT is:
  - A problem-solving process that includes:
    - Algorithmic thinking
    - Organizing data
    - Modeling and abstraction to represent data
    - Using a computer to solve problems
- CT is not programming
- But it is cognizant of the need to compute and the potential benefits of doing so

How should we think about a problem given that we can compute?

Computational Thinking: Longer-Range Goals

- Broadening participation in computing by making it relevant and accessible:
  - Produce materials that teachers can use to engage students
    - Drawn from daily life making them meaningful and relevant
    - Student-centered
    - Activity-driven
    - Encourage hands-on experimentation with computers
    - Open-ended, allowing for creativity and collaboration
  - Instill awareness of opportunities to think computationally



Engage students in thinking computationally!

Computational Thinking: Challenges

- The concept of CT is still evolving
- We hope modules will be included in a wide variety of courses
  - Computer Science, Math, Science, Art, Social Studies…
  - Desired expertise for authors and teachers will vary by module
  - To make modules accessible to a wide audience, they have “stand-alone” parts so that teachers do not have to commit to the full module immediately
- Computer Science is not a standard high school subject (and we are not targeting AP CS)

Bottom line: Many parts in motion

Example: It's an Electrifying Idea!

- Is an electric vehicle more expensive?
  - Formulating a cost of ownership model: abstraction, estimates, simplifying assumptions
  - Refining the model to make it more realistic
  - Using a computer and a spreadsheet model as a tool
  - Computational exploration and uncertainty
- Can you get there from here?
  - Correspondence between graphs and maps
  - Graph concepts: connectivity, paths, distance
  - Algorithms and efficiency
  - New apps

Fortuitous Fact: Teens find cars relevant!

Forthcoming Examples:

- *Network Capacity Expansion* introduces network models and uses dice to simulate network events (like new traffic)
- *Cooperative Games and Collusion* explores ways to incorporate programming into the topics (without programming):
  - Identification of Nash Equilibria
  - Calculation of mixed strategies
  - Simulations of games
- Privacy vs Data Analysis

Testing Materials

Prototyping Workshops

- A mix of:
  - High school students
  - Undergraduate research assistants
  - Evaluators
  - Module authors
  - Field-test teachers
  - Advisory board
- Plus. . .
  - Module drafts, pieces, ideas, fragments, etc.

Prototyping Workshops

- Yield:
  - Free-flowing workshop on what CT is and how it can be taught and learned; informed by stakeholders with <u>multiple perspectives</u>
  - <u>Early</u> feedback to authors on modules
  - Direct engagement of students in CT
  - <u>Unanticipated</u> ideas for new modules & activities (why didn't we think of that?!)
  - Undergraduate converts to mathematics and CS majors and minors

Prototyping Workshops

- Also highlight:
  - Challenges to implementation:
    - Alignment with standards
    - Teacher professional development
    - Difficult to maintain currency
  - Incredible opportunities:
    - Students are highly engaged
    - Rich authentic contemporary links to myriad subjects
    - Power of true appreciation of the value of CT
  - Much more work to be done.

Evaluation & Research

Evaluation: Similarities & Differences

- *Outcomes*
  - Student Outcomes
    - Student Attitudes and Beliefs
    - Content Knowledge
    - Skills
  - Individual Modules
    - Feasibility and Usability of materials
    - Implementation

Evaluation: Similarities & Differences

- *Data Collection Methods*
- *Implementation Expectations*
- *Duration and Intensity*
  - 2-5 Days vs. Entire Semester

Questions and Discussion