Interdisciplinary Materials for High School Classrooms:
Challenges and Impact

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Outline

- Overview of DIMACS HS projects
- Module ingredients
  - Development
- Testing
  - Research
- Module examples
  - Bio-Math
  - Computational Thinking
  - Sustainability
- Engaging teachers
- Wrap up

What is DIMACS?

- Center for Discrete Math and Theoretical Computer Science
- Established 1989
- 11-years as an NSF Science and Technology Center and sustained since
- Mission to catalyze research & education in DM/TCS

DIMACS particularly emphasizes integrating research & education

Sample Programs

- Reconnect conferences for college faculty
- Postdoctoral fellowships
- Graduate student research & fellowships
- Research Experiences for Undergraduates
- Programs for HS teachers & students:
  - Young Scholars
  - Leadership Program and successors
  - Modules development (today's talk)

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 Interdisciplinary 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.

Modules: A Chronological View

- 2012 Mathematical and Computational Methods for Planning for a Sustainable Future proposal was submitted to NSF to develop twelve high school week-long modules to be used across disciplines, and a green jobs book describing jobs of the future. This project will also include partner schools and a summer student workshop.

Project Ingredients

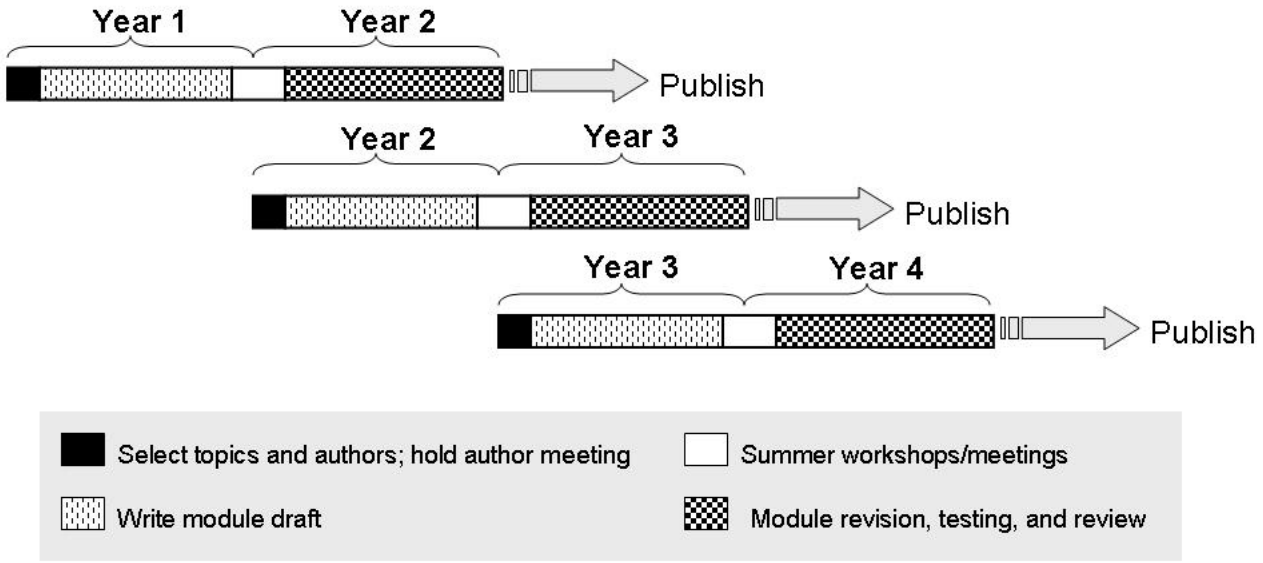
- Module Development
- Module Testing
- Research
- Student Engagement
- Teacher Engagement
- Dissemination
- Partners

Module Development

- Tasks:
  - Topic and Authors, content and pedagogy
  - Appropriate grade level(s) and classes
  - Goal(s) of the module
  - Full outline including unit's goals and objectives, and pacing
  - Content, materials, handouts, extensions, and assessments
  - Teacher edition (full) and student edition (subset of teacher edition)

A Rough Timeline

- Projects each have a similar structure
  - Specifics differ (particularly project duration)



BioMath – Imperfect Testing

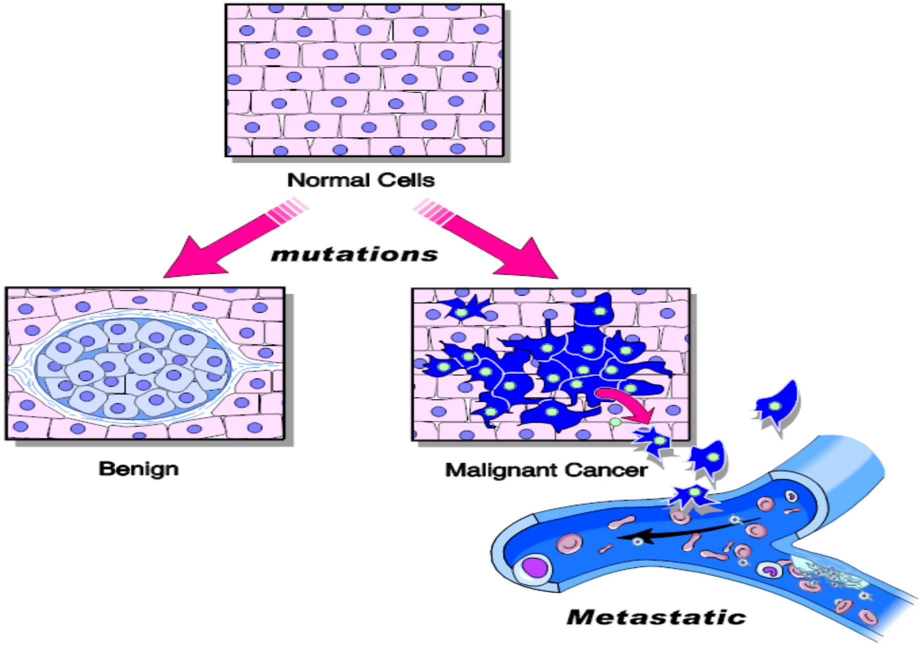
Content: genes, genetic testing and variation, mutations, probabilities including Bayes Rule, pharmacology, and decision making based on data for grades 10-12

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

BioMath - Imperfect Testing



BioMath – Imperfect Testing

Activities – Excerpts *from Cancer: A Dicey Situation*:

- Each group selects two students to roll the dice and two to do the recording. The two students roll one die each; one to represent a proto-oncogene and the other a tumor-suppressor gene. Each roller has 10 tries to roll a 1 (indicating a gene mutation). Rollers now simultaneously roll the dice and if rolling the same number (doubles) angiogenesis factors are released. (See module for continuation!)

BioMath – Imperfect Testing

Applications in Parallel Situations: Cancer Screening and Drug Testing

Test comparisons – Imperfect Word Search and Taste Test Activities

Pharmacogenetics: Web-based activities

http://learn.genetics.utah.edu/units/pharma/phsnipping/ and then go to http://learn.genetics.utah.edu/units/pharma/phfrogs/ to complete the **Pus-Poppin' Frogs** simulation on a computer

Assessments

BioMath – Imperfect Testing

Module Testing

- Pilot tested by experienced teachers, including authors Jim Kupetz and Tom Fleetwood and others
- Field tested by teachers recruited to attend a one-week summer workshop in the general area of the module – here in epidemiology
- Module is reviewed by math and biology content specialists
- Module is revised based on field testing and outside reviews

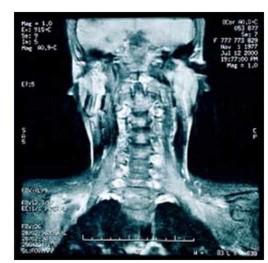
BioMath – Imperfect Testing

Research and Impact

- Evaluator observes at least one of the field test sites, and does phone interviews with students and teachers at all sites to determine teachability of the module. States using it include : MA, NY, NJ, PA, VA, MI, IN, IL, KA, MT, ND, CO, OK, MO, TX, SC, MI, GA, FL, AK, HI.
- Sample responses:
  - “They (students) were attentive, questioning, responded to questions, and deeply involved.”
  - “Yes, it was a different experience for them. They liked how we (the math and biology teachers) worked together on this.”
  - “Oh my gosh, YES! It was amazing to watch the students connect with this material.”

IMB - Tomography

- A module written for 12th graders that uses exponentials and systems of equations
- Where mathematics, biology and technology come together
- Considers many different applications of CT scans including food safety, structural integrity, virtual autopsies and more

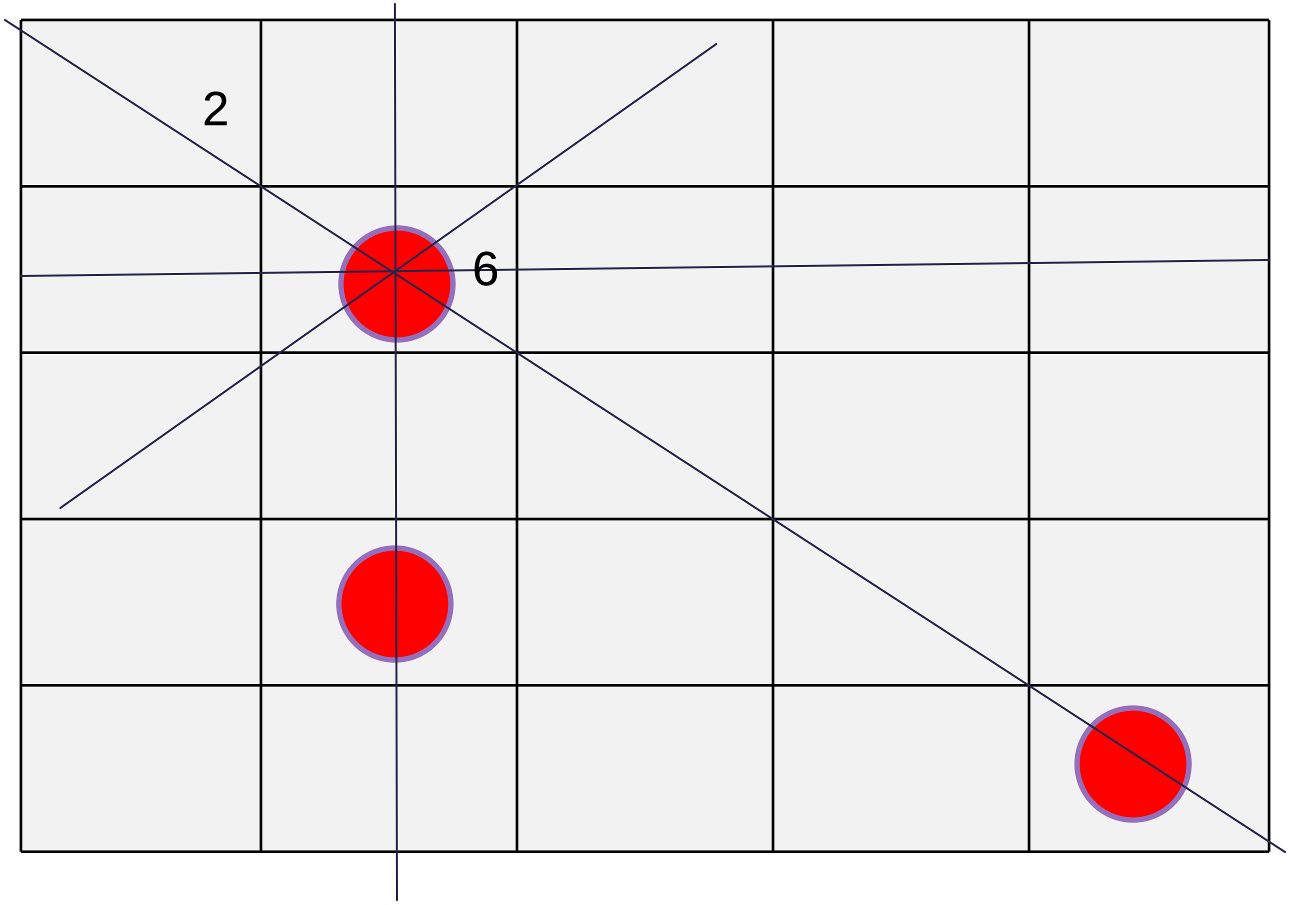


IMB - Tomography

Checkerboard Activity:

1. Each group needs a 5 by 5 paper “checkerboard” and 3 checkers (or pennies). Place 3 checkers anywhere on the checkerboard and assign a number to each square on the board as follows: Four lines pass through each square on the checkerboard: horizontal, vertical, and two diagonals. Count the number of checkers on each of the four lines passing through that square – the sum of those four numbers is the number for that square.
2. Given numbers on the board can you find the checkers?

IMB - Checkerboard Activity



IMB Testing

- Field testing only, no pilot testing of new modules – in at least 3 classes
- Research ongoing and includes testing a 12 grade semester book and year long book containing all 20 modules
- School in North Dakota has gained approval to offer a full year BioMath course as a 4^{th} year math or science course, using the BMC/IMB modules
- All partner schools will test a full set of modules

VCTAL: Immediate Goal

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

ISTE/CSTA: Computational Thinking

- Computational thinking (CT) is a problem-solving process that includes (but is not limited to) the following characteristics:
  - Formulating problems in a way that enables us to use a computer and other tools to help solve them
  - Logically organizing and analyzing data
  - Representing data through abstractions such as models and simulations
  - Automating solutions through algorithmic thinking (a series of ordered steps)
  - Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
  - Generalizing and transferring this problem solving process to a wide variety of problems

Further Thoughts on CT

- Computational thinking:
  - Is a high level thought process
  - Is not programming
  - Harnesses the power of computing to gain insights
  - Relates to mathematical thinking in its use of abstraction, decomposition, measurement and modeling, but is more directly 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?

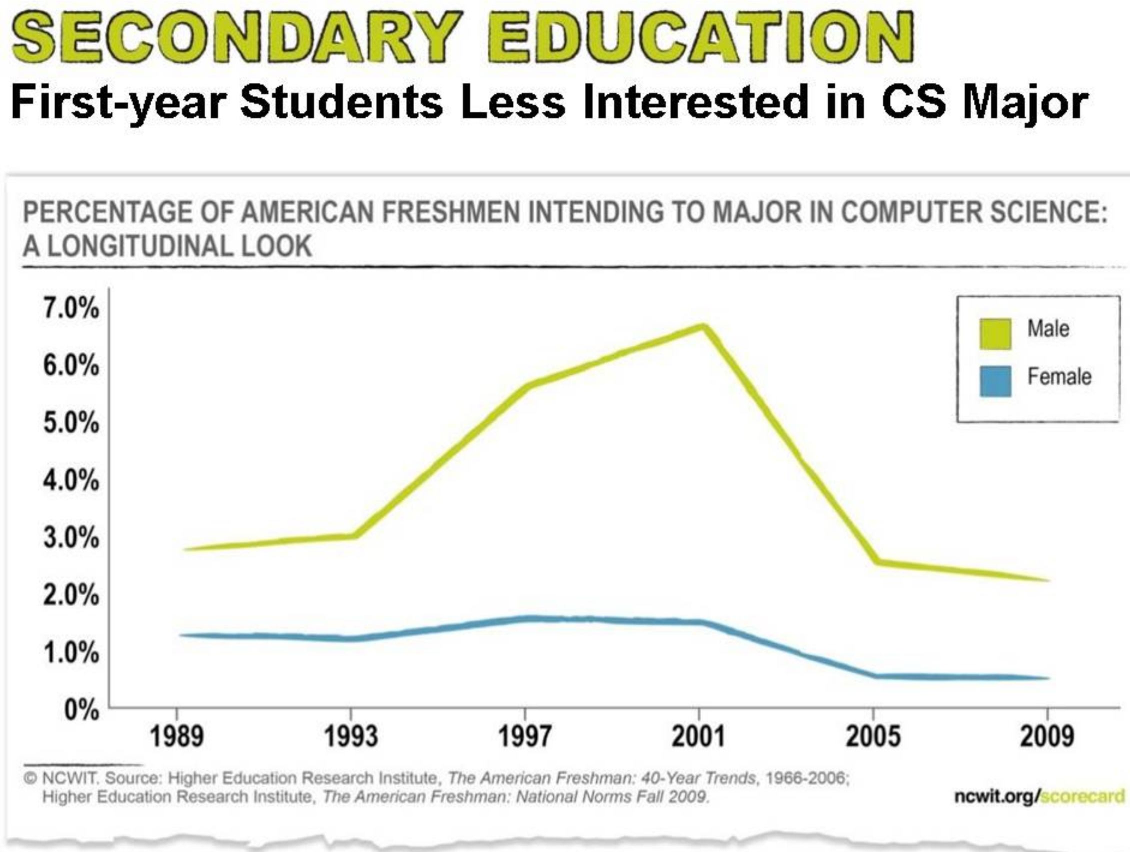
Putting the “C” in CT

- Some examples of where the “computational” part is important:
  - Really LARGE problems
  - Really HARD problems
  - Problems that involve interacting with computers
  - Problems containing uncertainty
  - Problems that are naturally viewed in the context of “algorithms”

VCTAL: Longer-Range Goals

- Broadening participation in computing by making it relevant and accessible:
  - Producing materials that teachers can use to engage students
  - Instilling awareness of opportunities to think computationally
  - Offering examples that show CT woven throughout daily life
  - Widely disseminating modules

Why Broaden?


SECONDARY EDUCATION
First-year Students Less Interested in CS Major
PERCENTAGE OF AMERICAN FRESHMEN INTENDING TO MAJOR IN COMPUTER SCIENCE: A LONGITUDINAL LOOK
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0%
1989
1993
1997
2001
2005
2009
Male
Female
© NCWIT. Source: Higher Education Research Institute, The American Freshman: 40-Year Trends, 1966-2006; Higher Education Research Institute, The American Freshman: National Norms Fall 2009.
ncwit.org/scorecard

Can Modules Broaden Participation?

- Studies show that girls (and other under-represented groups) respond positively to*:
  - projects they find personally relevant and meaningful
  - hands-on, open-ended projects
  - being able to approach projects in their own way
  - being encouraged to think critically
  - collaboration

VCTAL modules contain many of these elements

*Based on PBS SciGirls Seven

About the Modules - 1

- 4-6 days of classroom activities
- “Stand-alone” parts so that teachers do not have to commit to the full module
- Intended classes: not just CS or Math
  - Personal finance
  - Social sciences
  - Etc.
- Not targeting AP CS

About the Modules - 2

- Student-centered, activity-driven, problem-based
- Drawn from everyday life
- Encourage hands-on experimentation with computers
- Active, not passive
  - Activity
  - Discussion
  - Exercises

Engage students in thinking computationally!

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: Many teens find cars relevant!

Spreadsheet Activity: Buying a Car!

	$3.00	$3.25	$3.50	$3.75	$4.00	$4.25	$4.50	$4.75	$5.00	$3.67
Nissan Leaf	$31,416	$31,416	$31,416	$31,416	$31,416	$31,416	$31,416	$31,416	$31,416	$31,416
Civic Hybrid	$32,017	$32,627	$33,237	$33,846	$34,456	$35,066	$35,676	$36,285	$36,895	$33,651
Civic LX	$29,450	$30,312	$31,174	$32,036	$32,898	$33,760	$34,622	$35,484	$36,346	$31,760

Car specific parameters

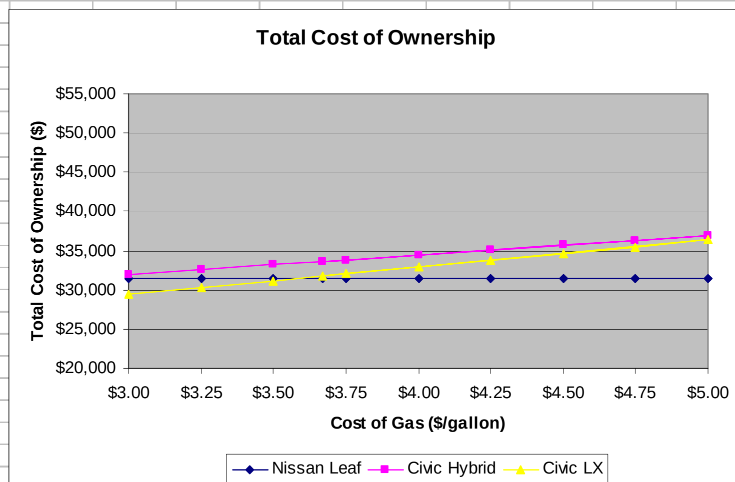
Initial cost	MPG	tax credit
$33,800	0	7500
$24,700	41	
$19,105	29	

Gas car parameters that do not

$/gallon	3.67
total miles	100,000

Electric car parameters

cents per kw-hour	11
kw-hr per charge	24
miles per charge	73
cost of charging dock	$1,500.00



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students should experimen
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The yellow cell above allow
any gas price that you'd lik
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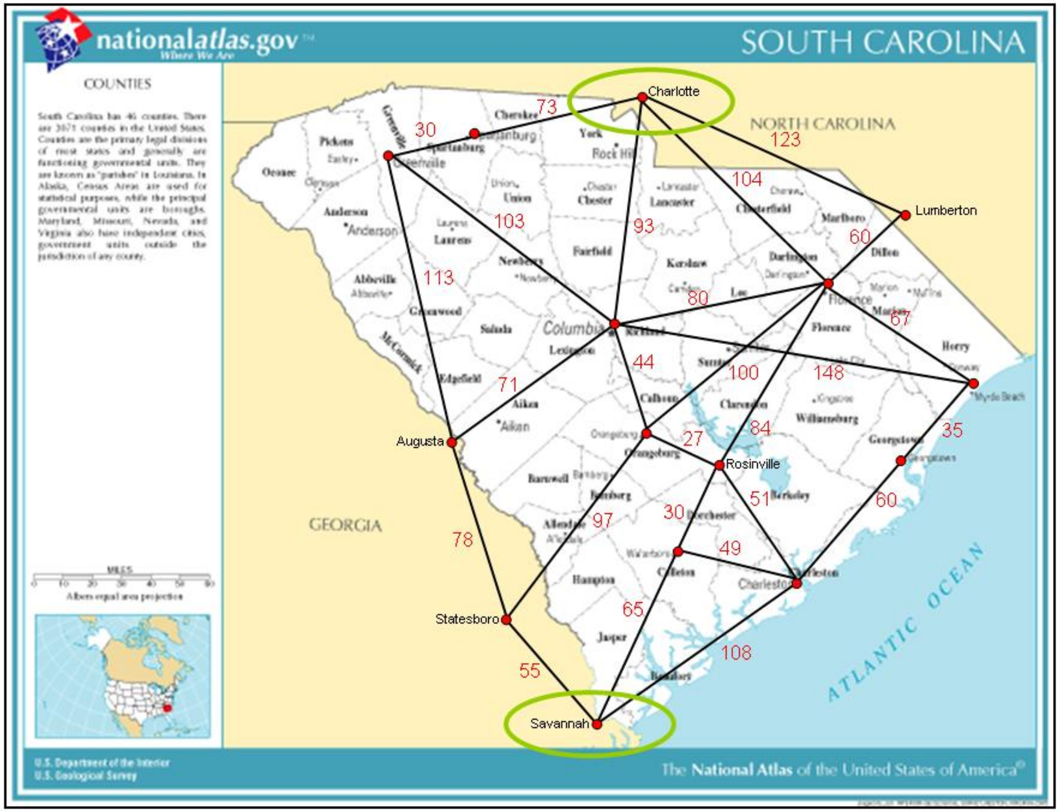
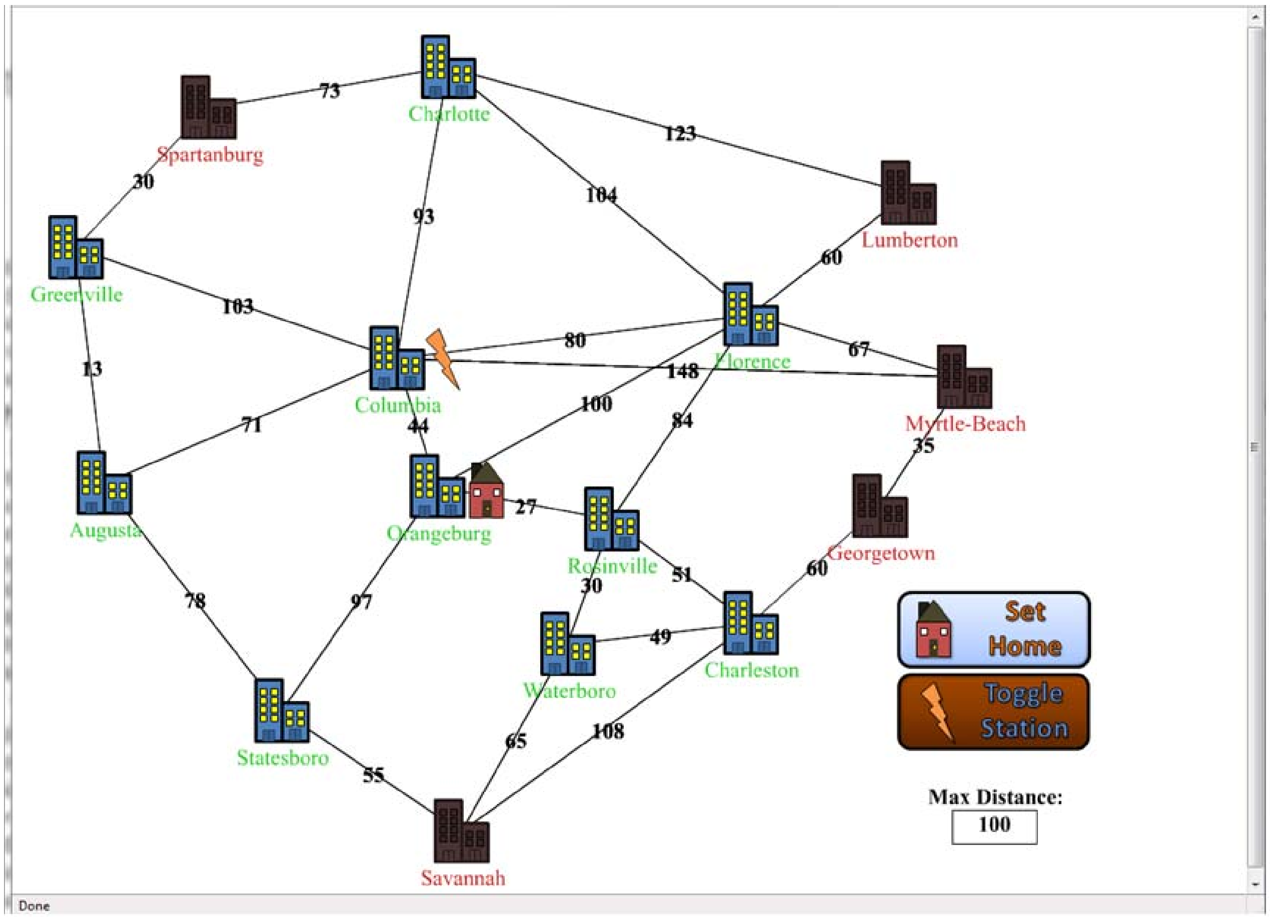
Driving Activity: Road Trip?



Driving Activity: Charge It!



Thanks: Scott Kulp, Rutgers

[Road Trip Applet]

VCTAL Testing

- Piloting with students in a Summer Prototyping Workshop
  - Material can be in “rough” form
  - Assess student response
  - Assess module teachability
  - Make adjustments for field testing
- Field testing at partner schools
  - Each module tested at least twice

- Module reviewed by content specialists identified by an Editorial Board
- Module revised based on field testing and outside reviews

Research & Impact

- Evaluator observes the summer workshop and does pre- and post-workshop surveys of students' attitudes about computer science, its utility, and interest to them.
- From the 2011 workshop report:
  - *All* indicated that the lessons helped them to see how computer science can apply to people's lives.
  - *All* participating students indicated that the VCTAL Summer Program changed their understanding of what computer scientists do.
- Evaluator observes some of the field test sites, and does phone interviews with students and teachers at all sites to determine teachability of the module.

Mathematical and Computational Methods for Planning a Sustainable Future (PS-Future)

- Math & CS have an important role to play in sustainability:
  - Design of efficient buildings (like solar)
  - Community planning
  - Allocation of resources
  - Analyzing data
- Applicable to a variety of classes
  - Math/Statistics
  - CS
  - Biology
  - Social Studies
- Empower students for civic engagement
- Build awareness of career paths

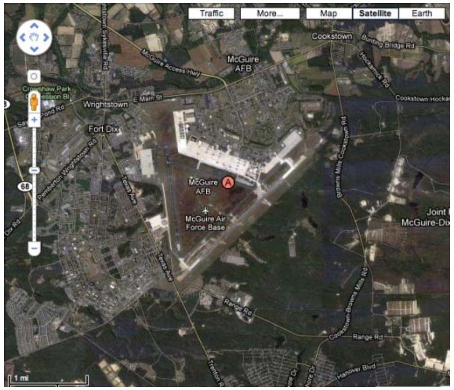
Overarching Goal: Make math & CS relevant!

Some Sample Topics

- Passive solar building design (geometry)
- Hydrologic Cycles (geometry)
- Spread of invasive species (discrete math)
- Exploring weather data (statistics)
- Cost analysis (algebra/pre-calc)
- Bike path planning (discrete math)
- Sustainable urban development (spatial mapping)

Example: NJ Weather

- NOAA has publicly available weather data from around the world
- Look at data from McGuire AFB
  - 55 years
  - Daily average temps, etc
  - Near coast
  - No urban heat effects
  - Do we see any trend?

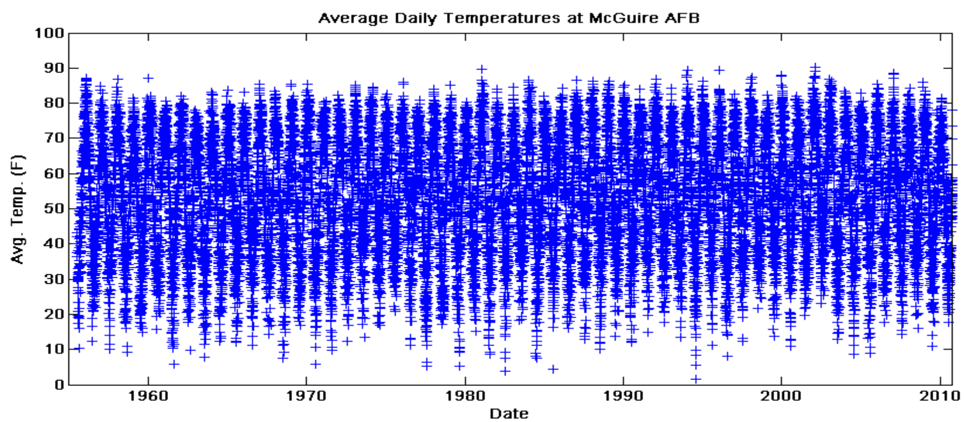


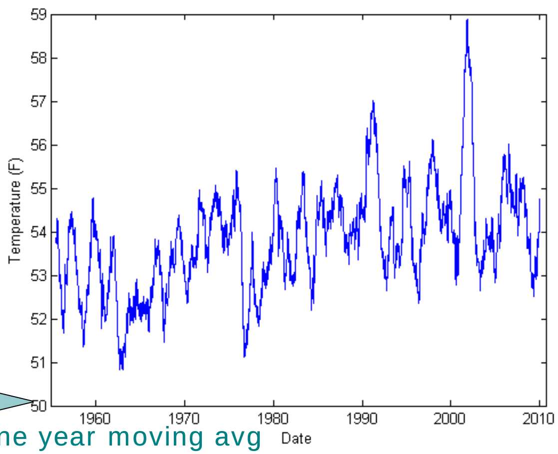
- Same techniques apply elsewhere

Encourage students to ask their own questions.
Give them tools to draw their own conclusions.

Thanks to Bob Vanderbei and Jon Kettenring

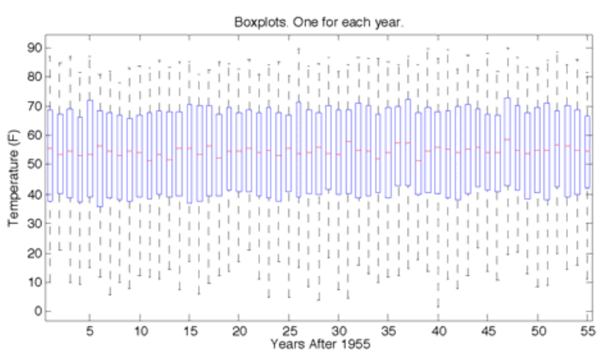
Looking at Data: The McGuire Case



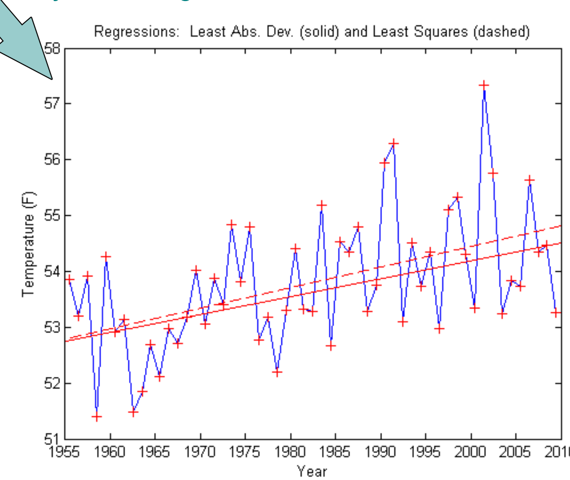


one year moving avg

one year averages



one year boxplots



Evaluation & Research

- Evaluation will have similar structure to VCTAL
- Student outcomes evaluated:
  - math and CS motivation and interest
  - knowledge acquisition
  - attitudes and behaviors related to sustainability
  - awareness of jobs and careers
- Teacher engagement
  - How the project facilitates use of modules

Teacher Engagement

- Transition from teacher workshops to partner schools spread across the country
- Online support system for years to come
- We have a total of nearly 300 teachers engaged in our projects and willing to do more
- Teachers are our best disseminators!
- Question: How do we engage preservice teacher education programs to include cross disciplinary work?
- How might you be involved?

Challenges

- Teachers often find it difficult to find enough time to incorporate an entire module, which generally takes five to seven class periods
- A formidable obstacle teachers cite is a lack of confidence with content from the other discipline
- It is difficult to determine appropriate grade levels for the modules

Thanks to our partners

- All of our teachers and partner schools
- Boston University
- Colorado State University
- COMAP
- Computer Science Teachers Association (CSTA)
- The Groton School
- Hobart William Smith Colleges
- National Center for Atmospheric Research (NCAR)
- The Rutgers Bloustein School

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Questions and Thank you