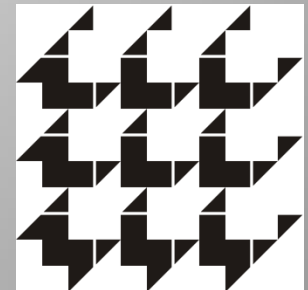# Developing Interdisciplinary Materials for 9-14 Classrooms

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MBI
July 29, 2013

Outline

- Overview of module development projects
- Module 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

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 12th grade mathematics or science courses or combined courses. Partner schools across the country play a key part. North Dakota will offer a full year BioMath course starting this year, and Massachusetts, Missouri, and Montana will offer a one semester course this fall and spring.

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 project is funded by NSF to develop 9-14 grade level week-long modules to be used across disciplines, and a green jobs book describing jobs of the future. This project also includes partner schools and a summer student workshop.

- **2012** MPE 2013 Module Project is developing one day undergraduate modules. It is supported by NSF funding for the mathematical and statistical challenges for sustainability workshop.

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)
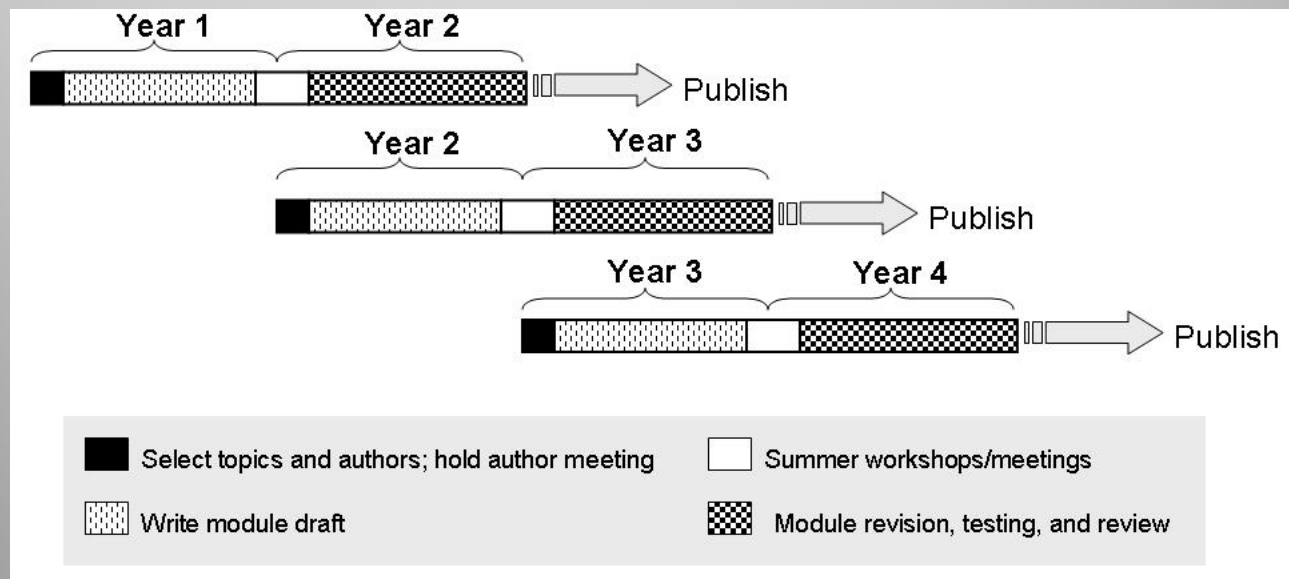
BioMath – Imperfect Testing

Content: genes, genetic testing and variation, mutations, probabilities including Bayes Rule, pharmacology, and decision making based on data - for grades 10-14
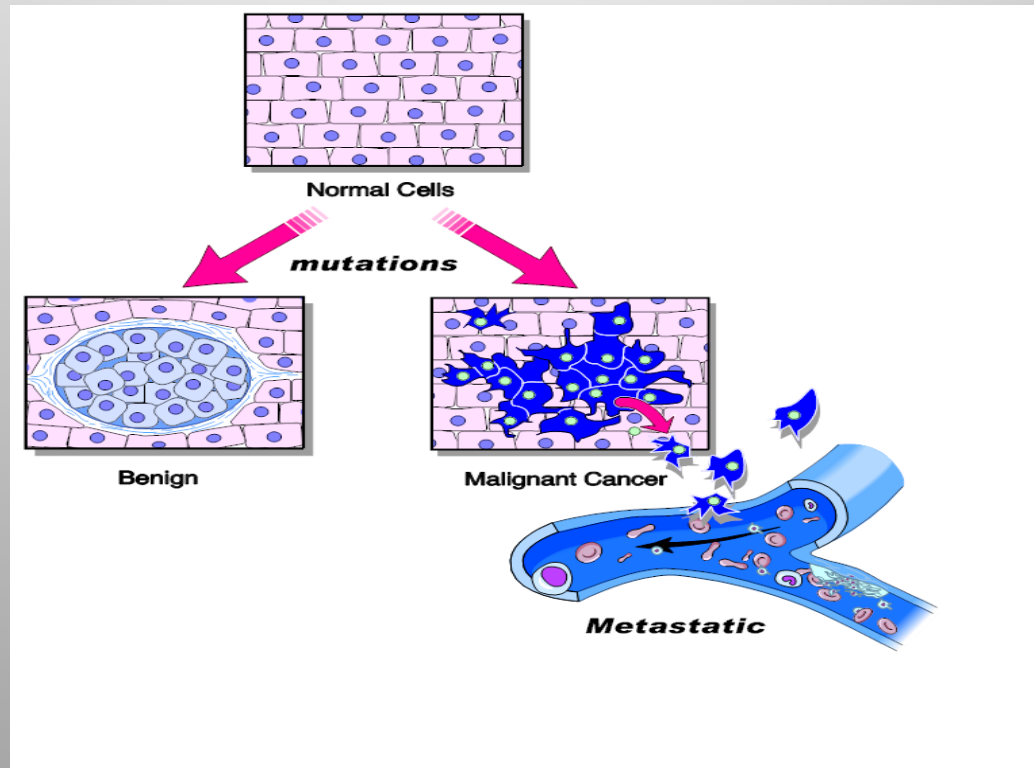
Case study approach:

- 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 initially recruited to attend a one-week summer workshop in the general area of the module – here in epidemiology, and later from partner schools

- 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, and its companion VCTAL module are written for 11-14 level classrooms that uses exponentials and systems of equations, and geometry for 3-D reconstructions
- 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
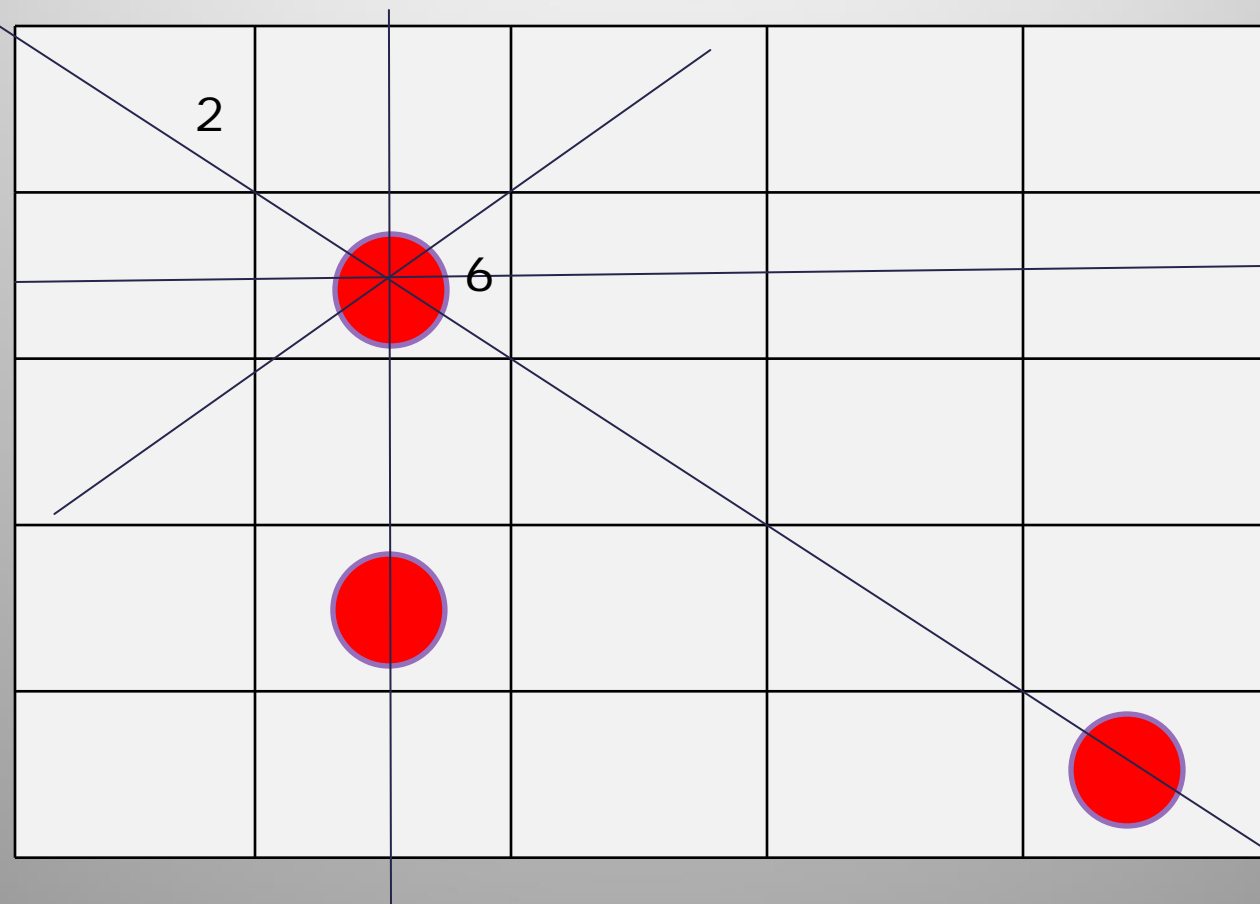
IMB Testing

- Field testing testing of new modules – in at least 3 classes

- Research ongoing and includes testing a 12th grade semester book and year long book containing all 20 modules

- School in North Dakota will offer a full year BioMath course this year as a 4th year math or science course, using the BMC/IMB modules

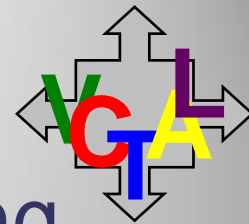- All partner schools will test a full set of modules
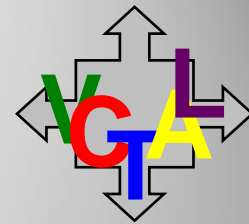
VCTAL: Immediate Goal

○ 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
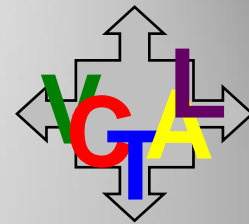
# Further Thoughts on CT

- Computational thinking:
  - Is a high level thought process
  - Considers the world in computational terms
  - Begins with learning to see opportunities to compute
  - Is not programming
  - 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
 - Harnesses the power of computing to gain insights

How should we think about a problem given that we can compute?
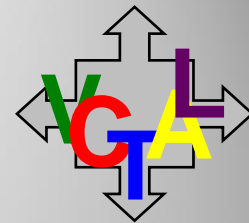
Putting the "C" in CT

○ 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"
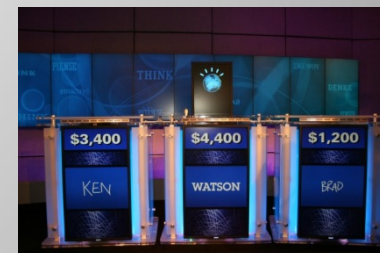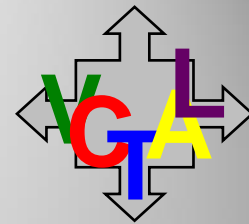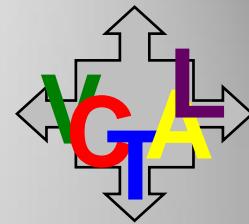
VCTAL: Longer-Range Goals

- 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
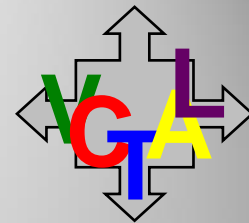 - Widely disseminating modules

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
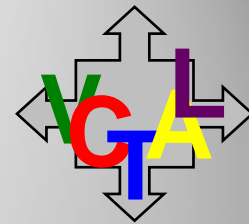 - Social sciences
  - Sciences.
- Not targeting AP CS

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!

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 Module revised based on field testing and outside reviews
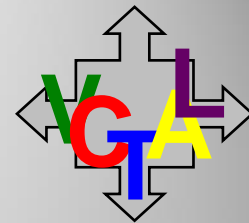
Research & Impact

- 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) and MPE Module Project

- ○ 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 (trigonometry and geometry)
- Weather Generators (statistics)
- Global Hydrologic Cycles (geometry)
- Spread of invasive species (discrete math), MPE Percolation module
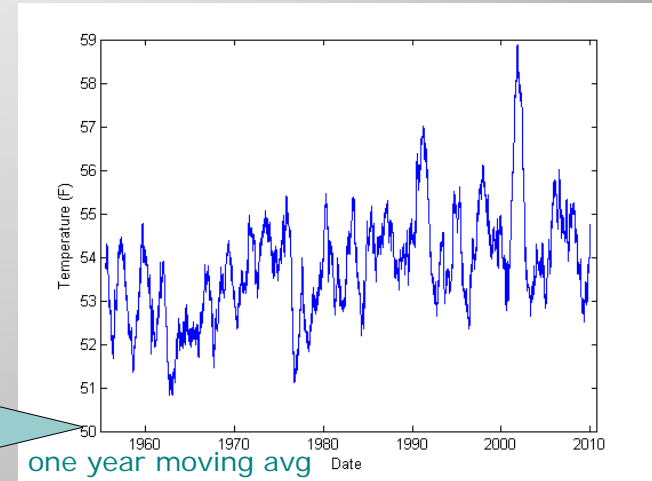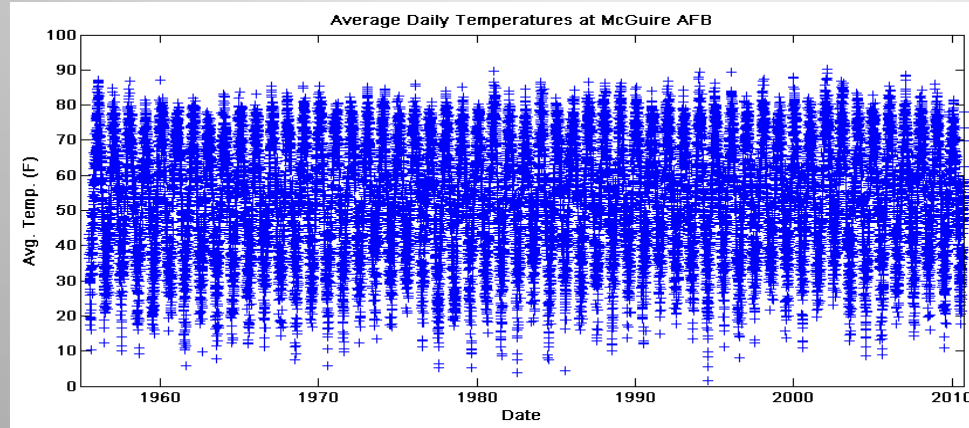- Sustainable urban development (spatial mapping)

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?
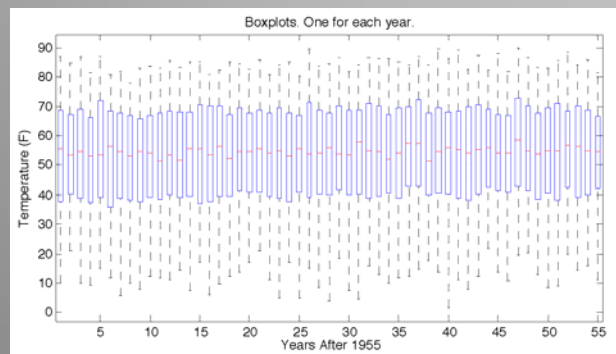- Same techniques apply elsewhere
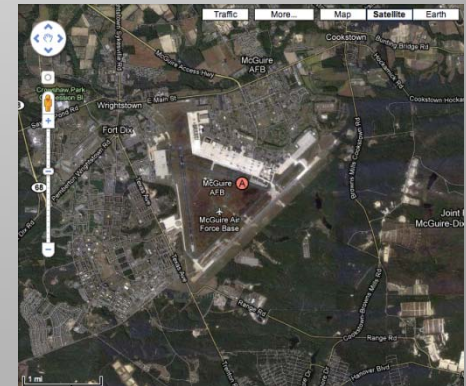
Encourage students to ask their own questions.
Give them tools to draw their own conclusions.
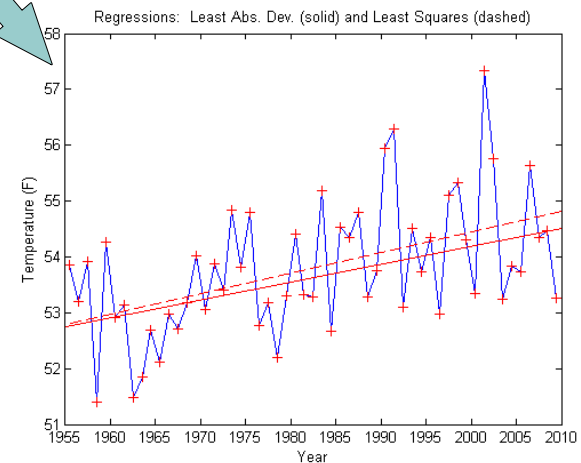
Looking at Data: The McGuire Case

Average Daily Temperatures at McGuire AFB

one year moving avg

one year averages

Boxplots. One for each year.

one year boxplots

Regressions: Least Abs. Dev. (solid) and Least Squares (dashed)

Evaluation & Research

- Evaluations have similar structures to VCTAL and IMB
- Student outcomes evaluated:
  - Environmental science, 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

Challenges

- Teachers often find it difficult to find enough time to incorporate an entire module, which generally takes five to seven class periods, even the shorter modules

- A formidable obstacle teachers cite is a lack of confidence with content from the other discipline

- It is often 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
- The Rutgers Bloustein School

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- DRL 1020166 (IMB)
- DRL 1020201 (VCTAL)
- DRL 1220022 (PS-Future)
- DMS 1053887 (Math)

And DHS CCICDA Grant

Websites

- IMB/BMC: dimacs.rutgers.edu/IMB
- VCTAL: dimacs.rutgers.edu/VCTAL
- PS-Future: dimacs.rutgers.edu/PS-Future
- MPE Module Project: dimacs.rutgers.edu/MPE

Questions and Thank you