Teach Your Children Well:
Sustainability Modules for High School Classrooms

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MPE 2013+ WS on Data-aware Energy Use

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Rough Outline

- Why modules?
- How does the development process work?
- Three sample modules:
  - Electric Cars
  - Passive Solar Homes
  - Weather Generators
- The future of PS-Future and other projects
- Other details

About the Modules - 1

- 4-6 days of classroom activities
- They “stand-alone”
  - Often with “parts” so that teachers do not have to commit to the full module
- They link to standards:
  - Common Core
  - NGSS
- Multiple disciplines:
  - Math/Science
  - Even social science, language arts, etc.

About the Modules - 2

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

Engage students in active problem solving!

Can Modules Broaden Participation in STEM?

- 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

Our modules contain many of these elements

*Based on PBS SciGirls Seven

HS Modules at DIMACS:
A Chronological View

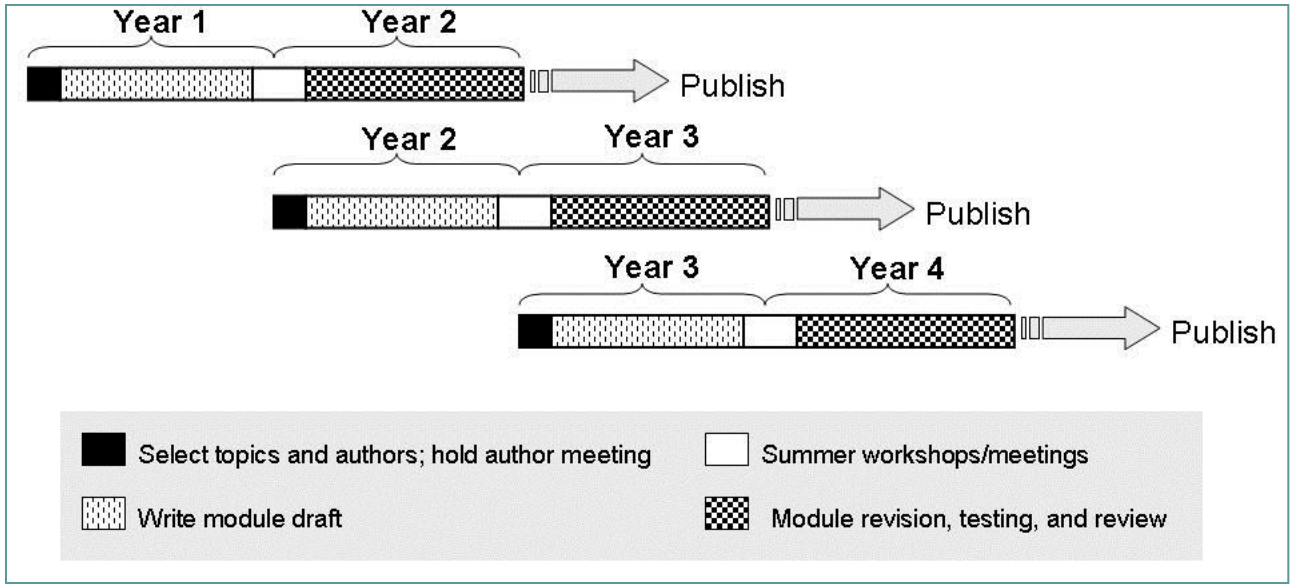
- 2006 BioMath Connection (BMC) five year project to develop 15 week-long modules in bio-math
- 2010 Interdisciplinary Mathematics and Biology (IMB) four year continuation of BMC to create five more modules and a 12th grade course
- 2010 The Value of Computational Thinking Across Grade Levels (VCTAL) four year project to develop 12 modules emphasizing computational thinking
- 2012 Mathematical and Computational Methods for Planning for a Sustainable Future (PS-Future) exploratory project developing 2 modules applying math and CS in sustainability contexts

It Takes a Village:
Module Project Components

- Authors: content and pedagogy expertise
- Summer workshop: early testing with students
- Partner schools: classroom field testing
- Advisory Board: guidance, topic selection
- Editorial Board: content review
- Evaluation: impact assessment

A Rough Development Timeline

- Projects have a similar (idealized) structure



Why Sustainability Modules?

- Sustainability context:
  - Is personally relevant
  - Spans many subjects
    - Biological sciences
    - Physical sciences
    - Social sciences
    - Math and computing
  - Naturally lends itself to formulating questions and exploring solutions

Why Sustainability Modules?

- Sustainability questions:
  - Are complex
    - Require modeling
    - Promote discussion
  - Involve use of data
  - Are ultimately about decisions & tradeoffs
    - Personal
    - Municipal
    - National
    - Global

Math & Computing are (in)valuable tools!

Example: It's an Electrifying Idea!

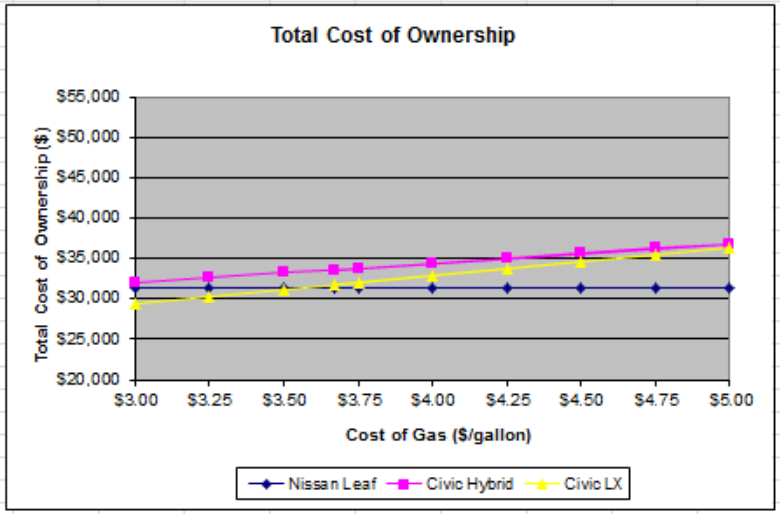
- Is an electric vehicle more expensive?
  - Formulating a cost of ownership model: abstraction, estimates, simplifying assumptions
  - Refining the model to make it more realistic
  - Using a computer and a spreadsheet model as a tool
  - Computational exploration and uncertainty
- Can you get there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

Fortuitous Fact: Many teens find cars relevant!

Spreadsheet Activity: Buying a Car!

ExploreCost-Lesson2 [Compatibility Mode]

	$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 vary by vehicle

$/gallon	3.67
total miles	100,000

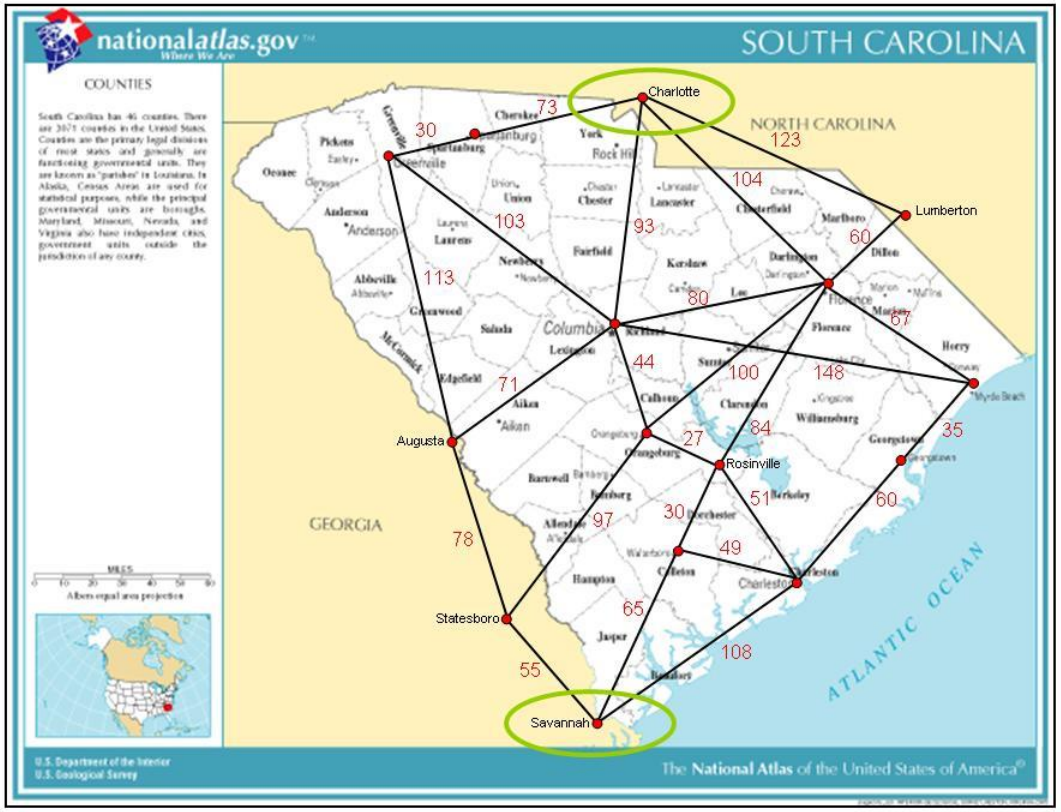
Electric car parameters

cents per kw-hour	11
kw-hr per charge	24
miles per charge	73
cost of charging dc	########

Cells in green contain parameters that students should experiment with using the scroll bars.

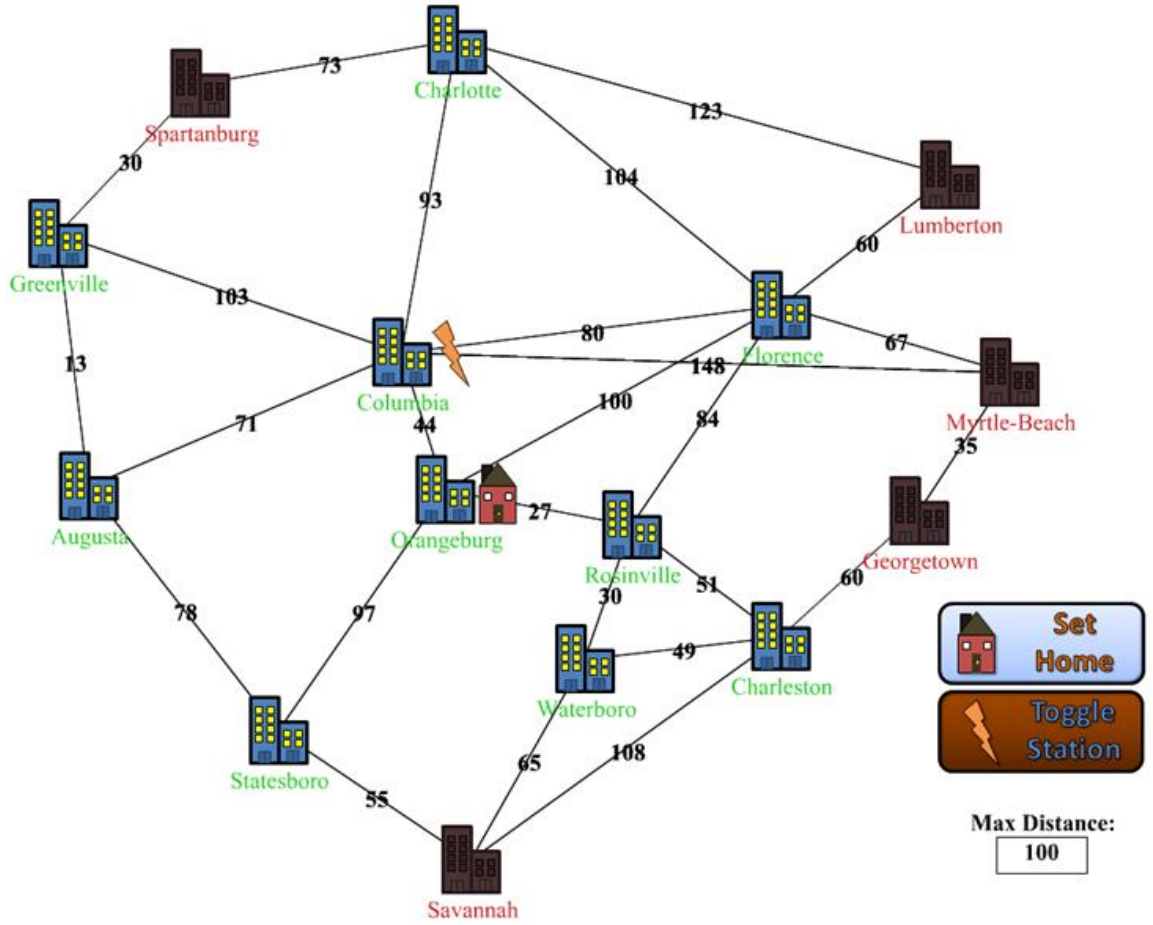
The yellow cell above allows you to enter any gas price that you'd like. The total cost of ownership using this gas price appears in the yellow column of the table. The points corresponding to this price are also included in the graph.

Driving Activity: Road Trip?



Using a graph to represent a map.

Driving Activity: Charge It!



Thanks: Scott Kulp, Rutgers

[Road Trip Applet]

Driving it Home: Outcomes

- Challenges what we think we know:
  - Electric cars may be cost effective
  - The range limit may not be so limiting
  - There's not always one answer!
- Teachers added "experiences" to content
  - Trip to electric car plant
  - Videos
- Students enjoyed modeling

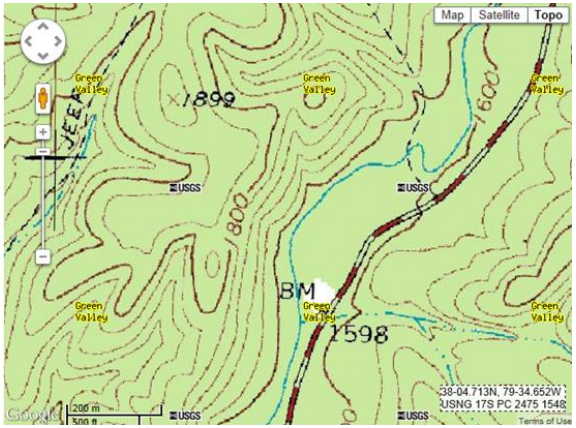
They wanted to keep adding more variables to their model to see how it would affect cost.

Example: Passive Solar Homes

- Students “design” a passive solar home
  - Uses the sun for heat in the winter
  - Blocks the sun to stay cooler in summer
- Why would we consider use of solar energy?
  - Economic advantages
    - Payback period
    - Cost stability
  - Environmental advantages
  - Political advantages
- What’s stopping us?
  - Initial investment
  - No centralized maintenance

Building a Passive Solar Home

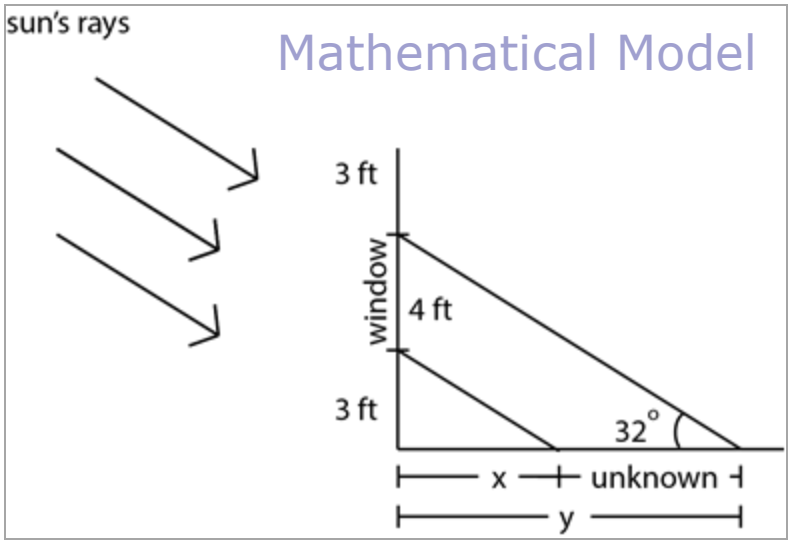
- Where should you put it?
  - Latitude
  - Temperature range
  - Topography (south slopes)
- How big are your windows?
- How long are the overhangs?
- What materials do you use?
  - Thermal mass affects temperature fluctuation



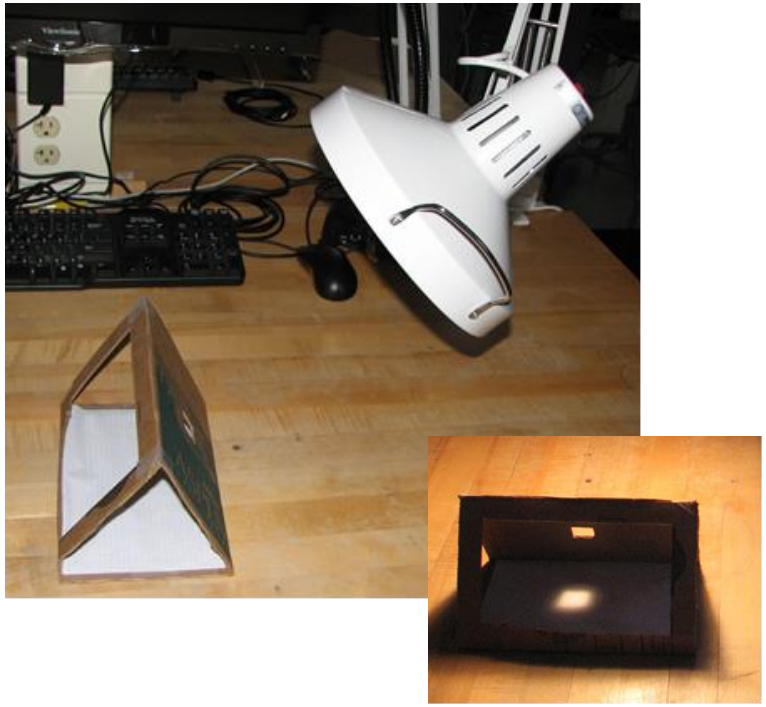
Let the Sun Shine In

- What floor area is hit by the sun?
  - Explore the relation between area and sun angle

Mathematical Model



Physical Model



Living in the Material World

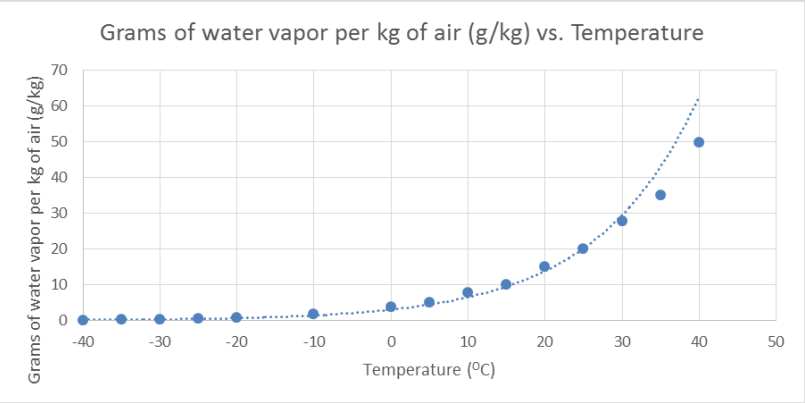
- How do building materials affect interior temperature?
  - Increasing thermal mass decreases temperature fluctuation

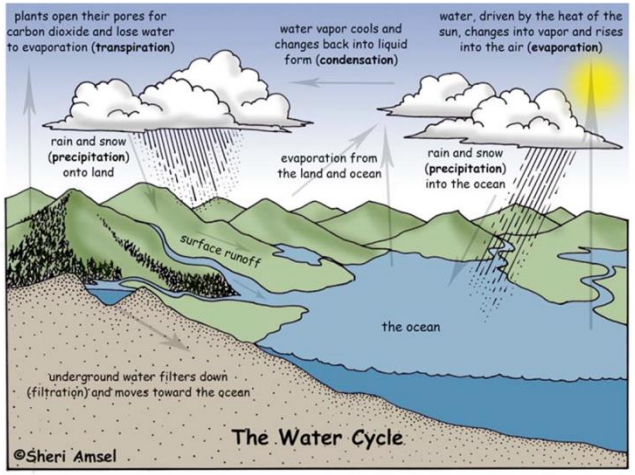
Some Comments

- Teachers
  - When students were creating structures using cardboard, lights, protractors … the students acted much more engaged.
  - This module is really helpful in getting students to think outside the box using different activities and incorporating science, math, design, etc.
- Students
  - I didn't even know about passive solar and it has really opened my eyes to inexpensive changes we can make when building homes.
  - My dad works for Spectra Energy and I am all of a sudden a lot more interested in what he does for work.

Example: Weather Generators

- Module connects climate change to the Water Cycle
- Global temperatures are rising.
  - What does that imply for the water cycle?
  - What does it imply about precipitation?
  - What does it mean for the planet?

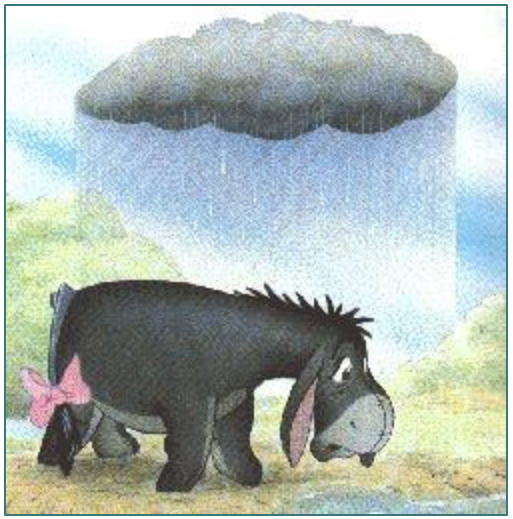




Weather Generator Concepts

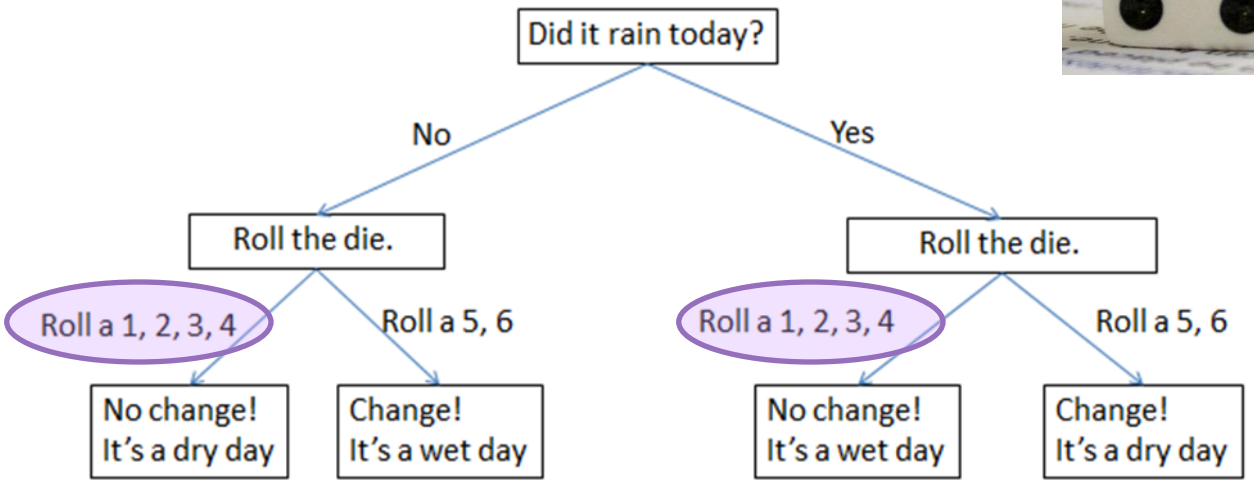
- Weather generator: statistical model used to generate realistic synthetic data
- Statistical persistence: randomness, but not independence

Weather over Eeyore exhibits statistical persistence.



A Simple "Weather Generator"

- Tomorrow's weather is more likely to be similar to today's weather



A Simple “Weather Generator”

- The 10-day forecast….

Starting weather is **Dry**

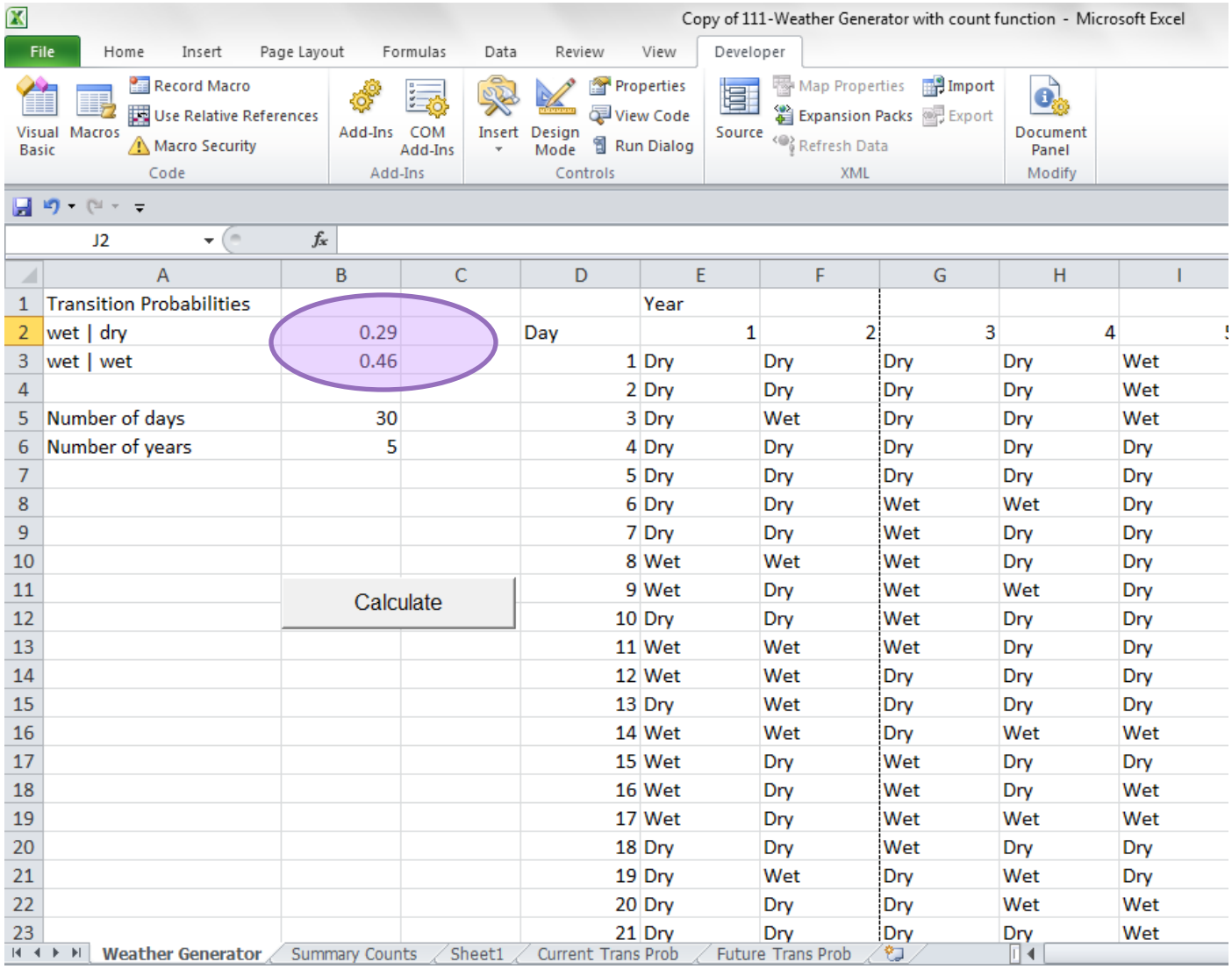
Roll	Today's Weather
1	Dry
2	Dry
3	Dry
4	Wet
5	Wet
6	Wet
7	Wet
8	Dry
9	Dry
10	Wet

2x2 Data Summary Grid

Yesterday \ Today	Wet	Dry
Wet	|||	|
Dry	||	||||

Persistence

A Better Weather Generator



	A	B	C	D	E	F	G	H	I
1	Transition Probabilities				Year				
2	wet | dry	0.29		Day	1	2	3	4	5
3	wet | wet	0.46		1	Dry	Dry	Dry	Dry	Wet
4				2	Dry	Dry	Dry	Dry	Wet
5	Number of days	30		3	Dry	Wet	Dry	Dry	Wet
6	Number of years	5		4	Dry	Dry	Dry	Dry	Dry
7				5	Dry	Dry	Dry	Dry	Dry
8				6	Dry	Dry	Wet	Wet	Dry
9				7	Dry	Dry	Wet	Dry	Dry
10				8	Wet	Wet	Wet	Dry	Dry
11		Calculate		9	Wet	Dry	Wet	Wet	Dry
12				10	Dry	Dry	Wet	Dry	Dry
13				11	Wet	Wet	Wet	Dry	Dry
14				12	Wet	Wet	Dry	Dry	Dry
15				13	Dry	Wet	Dry	Dry	Dry
16				14	Wet	Wet	Dry	Wet	Wet
17				15	Wet	Dry	Wet	Dry	Dry
18				16	Wet	Dry	Wet	Dry	Wet
19				17	Wet	Dry	Wet	Wet	Wet
20				18	Dry	Dry	Wet	Dry	Dry
21				19	Dry	Wet	Dry	Wet	Dry
22				20	Dry	Dry	Dry	Wet	Wet
23				21	Dry	Dry	Dry	Dry	Wet

Generating Ideas

- Generator transition probabilities:
  - Monthly
  - Past/Future
  - Several locations
- Pattern of wet/dry days is more important than averages
  - Longest wet/dry spells
- Persistence leads to longer wet/dry spells
- You can see seasonality in length of spells
- You can compare past to future

Some Comments

- Teachers
  - The data presented a whole lot of ambiguity. The students were not prepared for this. They are used to curves fitting nicely to the data. It was a strong example of what real-world science is like.
  - Classroom discussion was rich...
- Students
  - I didn't realize how much probability comes into play. I really enjoyed seeing these things mesh. It changes the way I see weather now.
  - By the end of the module I felt like there were more questions than when we had started. … This phenomenon makes me want to investigate the topic more and might be a great idea for my research project!

The Future of PS-Future

We are proposing to expand to new topics, possibly including…

- Hydrologic Cycles (geometry)
- Spread of invasive species (probability)
- Exploring weather data (statistics)
- Biodiversity (logarithms)
- Bike path planning (discrete math)
- Tragedy of the Commons (Game Theory)
- Sustainable urban development (spatial mapping)

To Learn More about DIMACS Modules

- PS-Future (sustainability) website:
  - http://dimacs.rutgers.edu/PS-Future/
- VCTAL (computational thinking) website:
  - http://dimacs.rutgers.edu/VCTAL/
- IMB (mathematical biology) website:
  - http://dimacs.rutgers.edu/IMB
- Also, MPE one-day undergrad modules:
  - http://dimacs.rutgers.edu/MPE/

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