Math and Sustainability Chicago Mathematics Symposium

Victor Donnay Department of Mathematics Bryn Mawr College vdonnay@brynmawr.edu

March 13, 2015

Introductions

Name

Institution

Course you teach which includes or might include issues of Civic Engagement

What is an issue facing the nation or the world that you are concerned about?

What are some issues facing the nation and the world that you are concerned about?

What are some issues facing the nation and the world that you are concerned about?

The goal of our math class is to show how the math we learn is connected to these issues you care about. What are some issues facing the nation and the world that you are concerned about?

The goal of our math class is to show how the math we learn is connected to these issues you care about.

Student Motivation

What the Best College Teacher Do

Ken Bain

Teaching Anatomy.

"If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."

Antoine de Saint-Exupéry As cited in *A Mathematician's Lament*

Thanks Ellie Goldberg, Brown Summer HS Program

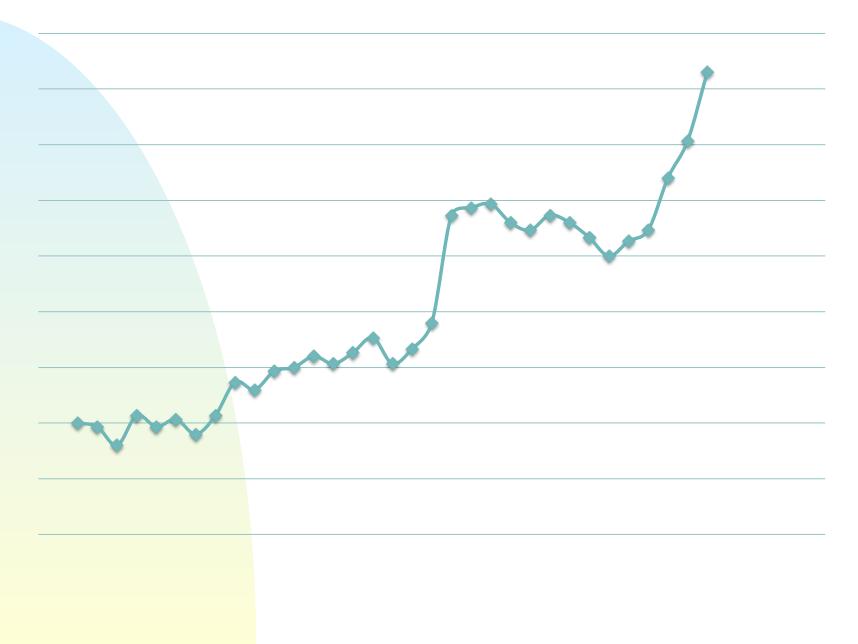
Any object not interesting in itself may become interesting through becoming associated with an object in which an interest already exists. The two associated objects grow, as it were, together: the interesting portion sheds its quality over the whole; and thus things not interesting in their own right borrow an interest which becomes as real and as strong as that of any natively interesting thing.

William James, Talks to Teachers, 1899.

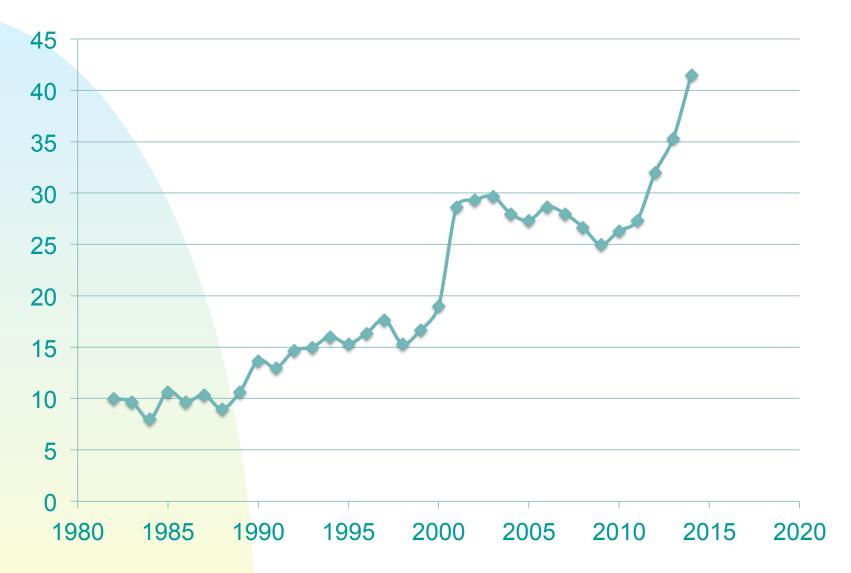
http://www.uky.edu/~eushe2/Pajares/tt10.html

Thanks David Burns, SENCER

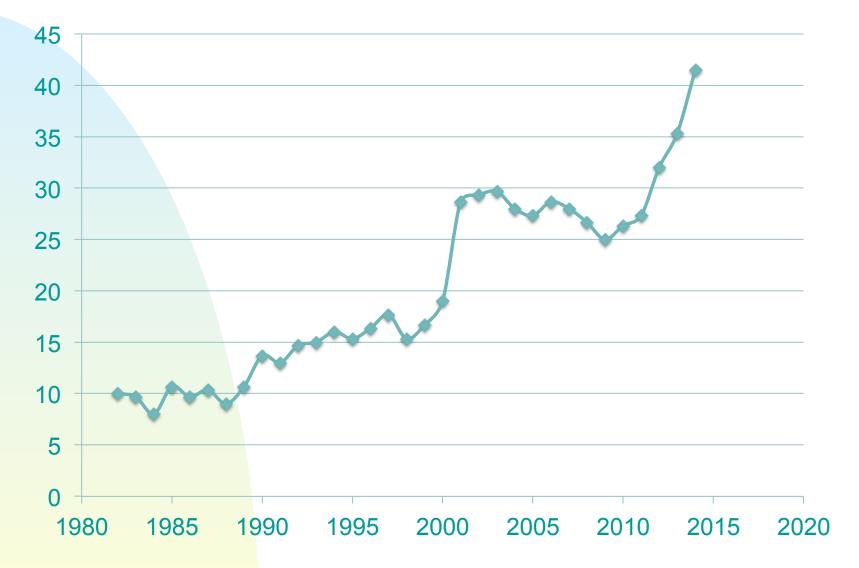
Data: What does this graph show?



Data:



Data: Number of math majors at Bryn Mawr





Winter 1990: Dean at a Research University

You can do those things here but

2012 AMS Exemplary Department Award

Bryn Mawr College's Math Department Wins American Mathematical Society's 2012 EXEMPLARY PROGRAM AWARD "The Bryn Mawr mathematics department has a long history of encouraging women to pursue careers in mathematics. By cultivating a special atmosphere—fun-loving yet serious, supportive yet challenging—the department has been enormously successful in attracting a diverse group of students." —American Mathematical Society



What are students interested in?

What are students interested in?

Ask them!

Assignment:

1. Connections Paragraphs:

Take a HW problem and describe how the mathematics involved might be used to address a real world problem.

Post your paragraph on Blackboard.

Calculus 1 and 2.

Related Rates:

1. A cylindrical tank with radius 5m is being filled with water at a rate of $3m^3/min$. How fast is the height of the water increasing?

Real World: How fast is sea level rising if the ice in Greenland is melting at a rate of 195 km³/year

2. Airplane A is going east at 420 mph. Airplane B is going north at 375 mph. How fast are they moving apart from one another.

Real World: Two children are born on the same day, same year. One child is born to middle class parents that hold professional jobs. The other child is born to poor working class parents. The vocabulary of the child with the middle class parents increases at 366 words per year. The vocabulary of the child with poor parents increases at 175words per year. How fast is the difference between vocabulary growths increasing in three years?

I ask this question in response to an article I read regarding the disadvantages that exist between socioeconomic classes and urban education. Reading this article provided evidence that there are so many factors that add to the gap that exist among education, specifically urban education where the majority of its students are part of poor/working class families.

Assignments:

2. Math to Life Connections - Final Project Multivariable Calculus

Take some topic in the world in which you are interested and some topic from our course and show how they are connected.

Thanks to Mrs. Jane Scanlon, Coopertown Elementary School 1st grade teacher.

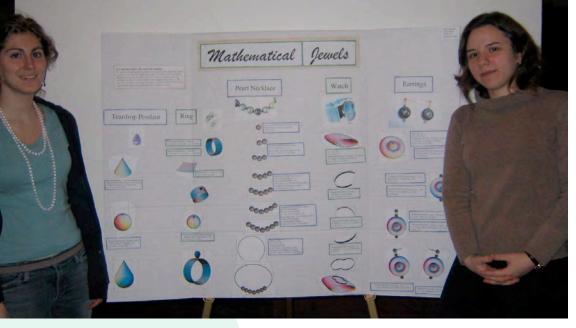
Everyday Math Program













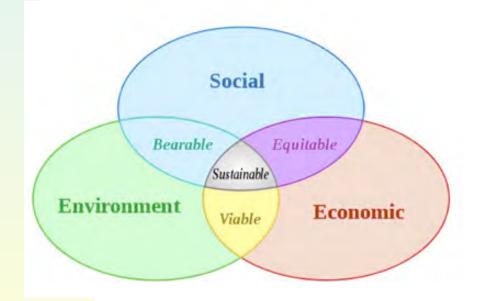


Math and Sustainability

- Interdisciplinary topic.
- Authentic issue facing the world.
- Math lessons that incorporate issues of sustainability.
 - Praxis (Service Learning) projects

Sustainability:

Meeting the needs of present and future generation by reconciling economic growth, social development and environmental protection.



Differential Equations and Modeling

Blanchard, Devaney, Hall text Dynamical Systems approach, Qualitative methods.

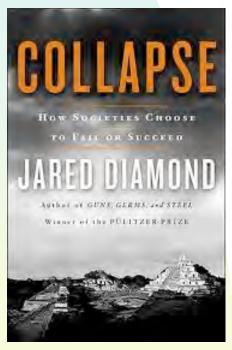
Environmental/Sustainability applications

Population Growth Bifurcations – Tipping Points

Use Readings from Interesting Books

Jared Diamond

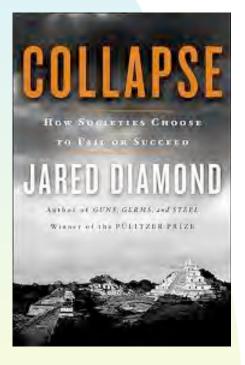
Collapse: How Societies Choose to Fail or Succeed.



What links do you see to topics from our course?

Jared Diamond

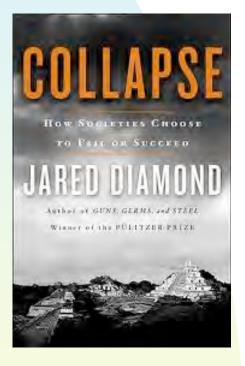
Collapse: How Societies Choose to Fail or Succeed.



Rwanda: Genocide

Jared Diamond

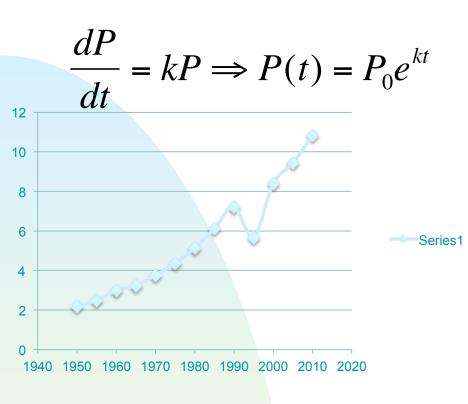
Collapse: How Societies Choose to Fail or Succeed.



Rwanda: Genocide Contributing factor: over-population

Population growth: Exponential

$$\frac{dP}{dt} = kP \Longrightarrow P(t) = P_0 e^{kt}$$



	Rwanda Population
Year	(millions)
1950	2.186
1955	2.485
1960	2.993
1965	3.233
1970	3.754
1975	4.359
1980	5.141
1985	6.113
1990	7.214
1995	5.664
2000	8.396
2005	9.429
2010	10.814

Population Growth

- 1. What does the book claim is the relative growth rate of the Rwanda population (k value)?
- 2. What would be the doubling time with this relative growth rate?
- 3. Looking at the population data table, calculate the relative growth rate (k) of population using the data from 1980 and 1985.
- 4. With this k value, predict Rowanda's population n in 1995. Does your prediction agree with the value given in the table? Discuss reasons for the difference.

Population growth:

What are problems with the Exponential Model?

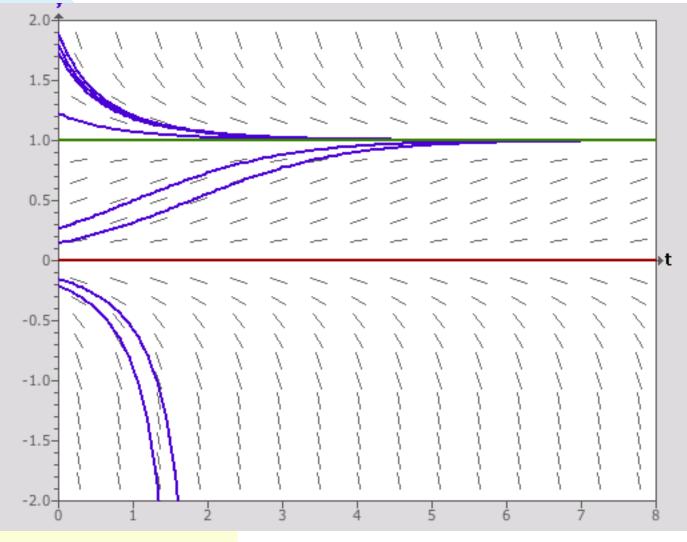
Population growth:

What are problems with the Exponential Model?

Logistic model – limits to growth Carrying capacity N

$$\frac{dP}{dt} = kP(1 - P/N)$$

Logistic Population growth: $\frac{dP}{dt} = kP(1 - P/N)$



Logistic Population growth with harvesting

"a" members of population harvested per year

$$\frac{dP}{dt} = kP(1 - P/N) - a$$

What types of populations can be "harvested"?

Logistic Population growth with harvesting

"a" members of population harvested per year

$$\frac{dP}{dt} = kP(1 - P/N) - a$$

What types of populations can be "harvested"?





Lead-in to Tipping Points

Lead-in to Tipping Points

Collapse



Easter Island

Lead in to Tipping Points

Collapse



Easter Island

What factors contributed to the collapse of the society?

Fishbanks: A Renewable Resource Management Simulation



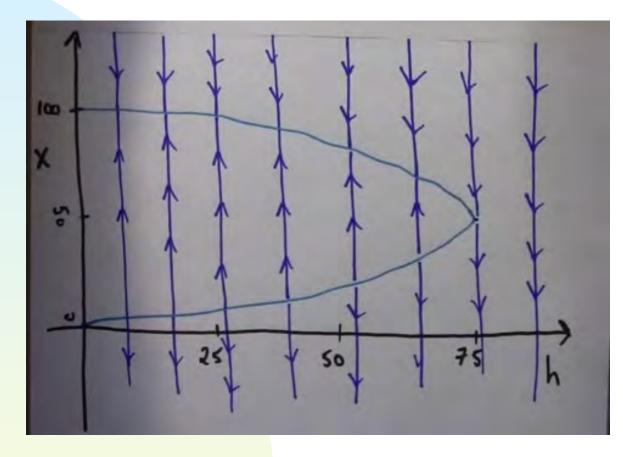
DEVELOPERS Dennis Meadows, John Sterman and Andrew King







Bifurcation Diagram



Created by class via "jig-saw" exercise.

See YouTube video by Jacob Bains: https://www.youtube.com/watch?v=ayuqqcOjBnQ

Bifurcation – Tipping Point:

A small change in the condition of the system (parameter) can lead to drastically different outcomes.

Critical value a_{cr} of fishing/harvesting levels

If
$$a > a_{cr}$$
 then the population will *crash*

$$\frac{dP}{dt} = kP(1 - P/N) - a$$

"a" fish caught per year



TED Ed

Is our climate headed for a mathematical tipping point?

TED Ed

http://ed.ted.com/lessons/is-our-climate-headed-for-mathematical-chaos-victor-j-donnay#review

Is our climate headed for a mathematical tipping point?



Climate Change Implications:

If temperatures increase by more than 2 °C (3.6 deg F) compared to pre-industrial level, there will be run-away climate change (collapse) – positive feedbacks.

Climate *bifurcation/tipping point*

What CO2 levels correspond to 2 °C temp increase?

Pre-industrial: 280 ppmDoubling: 560 ppmNew models suggest tipping point is lower: 450 ppm would only
result in a 50% likelihood of limiting global warming to 2 °C,

Necessary to achieve stabilization below 400 ppm to give a relatively high certainty of not exceeding 2 °C.^[5]

Incorporate Sustainability Into Courses

Inspired by Tom Pfaff, Ithaca College



http://www.sustainabilitymath.org/

Teaching units on sustainability for a variety of courses

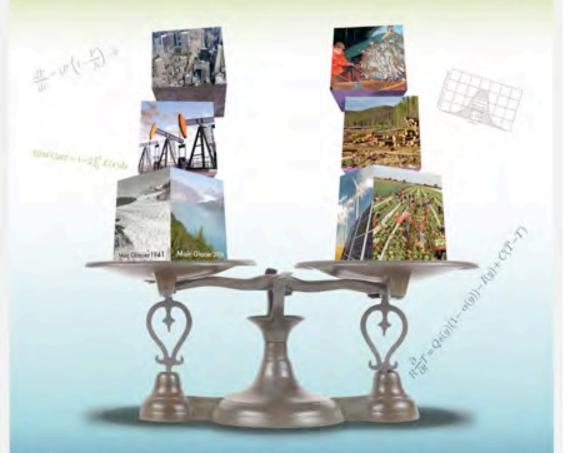
Mathematics Awareness Month 2013

On Aug 30, 2012, at 8:00 AM, Robert Daverman, AMS Secretary wrote:

Dear Professor Donnay,

I am writing with hopes of interesting you in chairing the Advisory Committee for next year's Math Awareness Month. You come highly recommended by leaders of the four primary mathematics societies in North America. The theme will be "Mathematics and Sustainability", which ties in neatly with next year's MPE2013 effort. Probably you know about the annual MAM campaign, which is a major Outreach program sponsored by the AMS, ASA, MAA and SIAM, and produced through the Joint Policy Board for Mathematics. http://www.mathaware.org/ mam/2013/

Mathematics Awareness Month - April 2013 Mathematics of Sustainability



Balancing needs and seeking solutions for a complex changing world

s learn more about the connections between mathematics and sustainability, visit



www.mathaware.org

Joint Policy Board for Multivenation American Multivenation Sciency, Mathematical Association of America, Society for Instantial and Agained Mythematical, American Statistical Association

Mathematics Awareness Month 2013: The Mathematics of Sustainability

http://www.mathaware.org/mam/2013/

Essays at: http://www.mathaware.org/mam/2013/essays/

Sustainability Counts! Educational materials: http://www.mathaware.org/mam/2013/sustainability/

Teaching Units:

- CO2 levels
- Artic Sea Ice
- Solar Panels
- Is it "worth it" to change light bulbs? (not at Mathaware site)

Other Resources: http://www.mathaware.org/mam/2013/related/

<u>The Practical, the Sublime, and the Sinister</u> by David Shiller, Lighting Solution Development

Why do we have a global environmental crisis? How did humanity get to this point? The deeper I dug, the more philosophical the issues became.....

Descarte Rationalist, mechanistic, and reductionist thinking

Mathematical ideas shape our worldview that man as separate from and above nature.

Our mathematics is a direct contributor to the global environmental crisis.

Math Modeling and Sustainability Course

Taught at various levels: Gen Ed, math major course, senior seminar, Secondary teacher institute

Grew out of Math Modeling in the Environment (C. Hadlock)

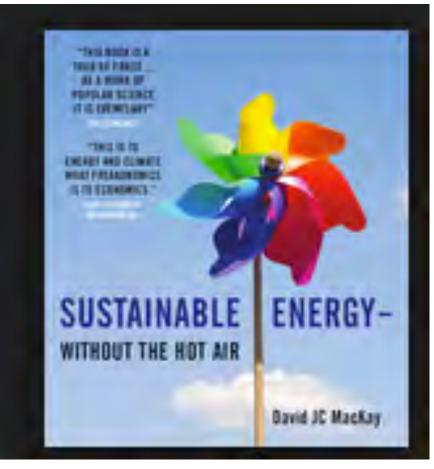
- Tom Pfaff Sustainability modules
- Ground water flow, Laplace equation
- Solar energy, solar panels, wind turbines
- House heating and energy use: insulation (R factor), windows, leakage
- Service Learning: student projects in partnership with community

Bryn Mawr has signed the Presidents 'Climate Commitment.

Sustainability Projects for Math Senior Seminar

- Trays in dining hall
- Energy savings in buildings from conservation mode.
- Pay back time for LED bulbs.
- Paperless admissions system
- Level of safety for bike routes
- On/Off switch for Chemistry hoods.
- Composting
- Trash audits
- Alternative Energy for recreation center

Sustainable Energy without the Hot Air David JC MacKay



http://www.withouthotair.com/

Math and Sustainability Summer Institute for Teachers

All materials from this institute available free at:

https://docs.google.com/document/d/1Ma9wYo83i10OLBf6R8WdYov0pd534n0yZbcObScYMUw/edit

and the second	Basic 75	Smort	Phillips
Brightness	1190	1200	1100
(lumens)	5700	4600	2060
Power .	75	90	17
(Watts)	71	19	15
Heat (°F)	238	159	88
Cost (\$) Eper bulb] *Tubulor f	1 1200/s	5 10pm ha	40 So, an Lis 165 (3)
were measu	med to	r neur	output
Result: 12 Further Inv - surface area	+ F	\$ a. 50	per bulb



Is it "worth it" to change bulbs?









Math and Sustainability Summer Institute for Teachers



Sustainability Starts Small

ARTS ACADEMY AT BENJAMIN RUSH







