

# Re-Numerate

restoring essential numerical  
skills and thinking  
via astronomy education

**SHOULD** Can it be done?

Kate Brutlag Follette

Dr. Don McCarthy

Dr. Erin Dokter

October 13, 2012



THE UNIVERSITY  
OF ARIZONA

# Innumeracy/Quantitative Illiteracy

**Table 1.** Common mathematical misconceptions encountered frequently in our classrooms.

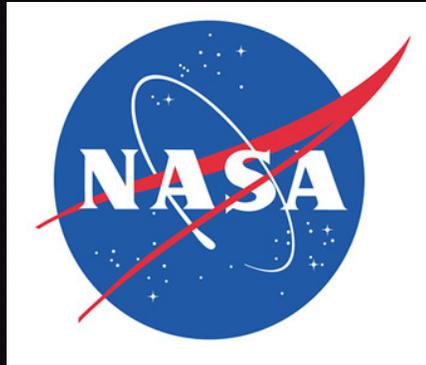
Operation	Common Incorrect Answer
$1 \div 5$	0.5
$0.5 =$	5%
How many seconds in an hour?	$60\text{sec}/\text{min} + 60\text{min}/\text{hr} = 120\text{sec}$
$10^2 =$	20
$4.3 \times 10^6 =$	4.3000000

- ❖ Motivation
- ❖ Study Basics
- ❖ Preliminary Results
- ❖ Implications and Future Plans



Kate Follette  
University of  
Arizona  
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# Voters, Consumers, Citizens

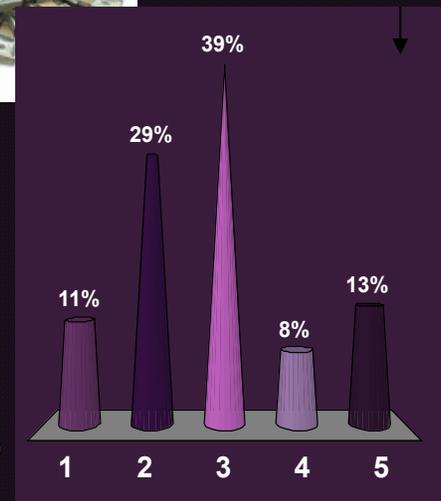


NASA's 2011 Budget:  
\$18.724 billion

US 2011 Budget:  
\$3.630 trillion



Who Wants to be a Billionaire?  
Where is one billion on this scale?



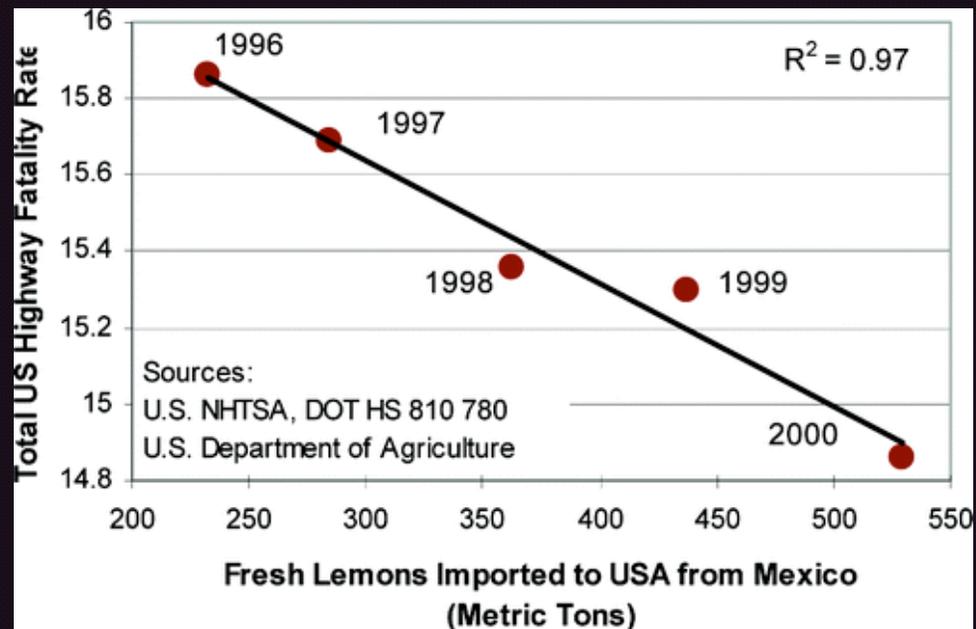
# Pseudoscience

- ◇ Motivation
- ◇ Study Basics
- ◇ Preliminary Results
- ◇ Implications and Future Plans

Kate Follette  
University of  
Arizona  
NNN 2012  
October 13, 2012

“I have here in my hand a list of 205, a list of names that were made known to the Secretary of State as being members of the Communist party and who nevertheless are still working and shaping policy in the State Department”

Joseph McCarthy February 9, 1950



# Why Intro Science/ Astronomy?

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

“I have always heard a lot about science and math being related, but I have never actually used them together. I have finished an entire year of algebra, but there has never been any science in it. The same holds true in my science class. Frankly, I have never seen any connection between the two of them.”

- ✧ Based on AIP survey: “introductory astronomy enrollments have remained in the 180,000-190,000 range since 2004” (Nicholson and Mulvey, 2010)
- ✧ + community colleges, where “an estimated 100,000 students take Astronomy 101 in departments not covered by the AIP survey” (Fraknoi 2001).
- ✧ Bureau of Labor Statistics: 2.2 million people were enrolled in college in the US in Fall, 2010.
- ✧ >10% of college students eventually pass through the door of an “Astronomy 101” course in college.

Can you do Division? Divide a loaf by a knife - what's the answer to *that*?  
*Through the Looking Glass*

## Part I: Skill Set

- ✧ Motivation
- ✧ **Study Basics**
- ✧ Preliminary Results
- ✧ Implications and Future Plans

# Numerical Skills

- ✧ Percentages and Fractions
- ✧ Multiplication and Division
- ✧ Simple Unit Conversions
  - ✧ Powers and Area
  - ✧ Estimation
  - ✧ Error
- ✧ Graph Reading and Interpretation

Kate Follette  
University of  
Arizona  
NNN 2012  
October 13, 2012

# Sample Questions

- ◇ Motivation
- ◇ **Study Basics**
- ◇ Preliminary Results
- ◇ Implications and Future Plans

Kate Follette  
University of  
Arizona  
NNN 2012  
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You get a letter from your cable company saying that they will be raising your monthly rate by \$5. Assuming that the rate does not change again, how much **additional** money will you be paying to the cable company over the course of the next **three** years?

- (a) \$60
- (b) \$100
- (c) \$130
- (d) \$180

How confident are you in the answer you just selected?

- (a) very confident
- (b) Confident
- (c) not very confident
- (d) I guessed

- ◇ Motivation
- ◇ **Study Basics**
- ◇ Preliminary Results
- ◇ Implications and Future Plans

## Sample Questions

You begin by measuring out the peanut butter in a 2 cup glass measuring cup like that shown above. You fill it to the  $\frac{3}{4}$  cup line. If you are to add the shortening to the same measuring cup on top of the peanut butter, which line should you fill it to?

- (a) the 1 cup line
- (b) the  $1 \frac{1}{4}$  cup line
- (c) the  $1 \frac{1}{3}$  cup line
- (d) none of the above



# Preliminary Survey

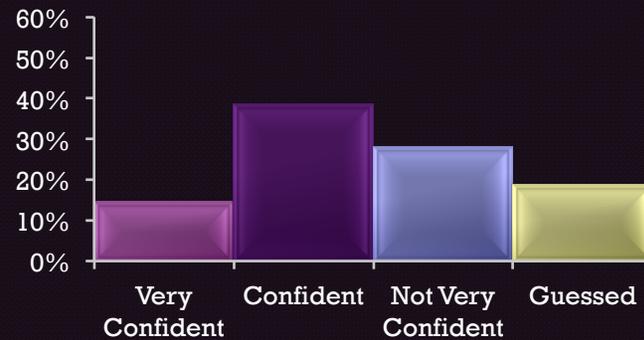
- ◇ Motivation
- ◇ Study Basics
- ◇ Preliminary Results
- ◇ Implications and Future Plans

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University of Arizona  
NNN 2012  
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### Confidence in Correct Answers



### Confidence in Incorrect Answers



Actual Score ~10% lower than Predicted Score

Fall, 2011

- ◇ Motivation
- ◇ Study Basics
- ◇ Preliminary Results
- ◇ Implications and Future Plans

- ◇ 2 classes
  - ◇ 1 large (188 students)
  - ◇ 1 small (26 students)

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University of  
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- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

## Inclusion Criteria

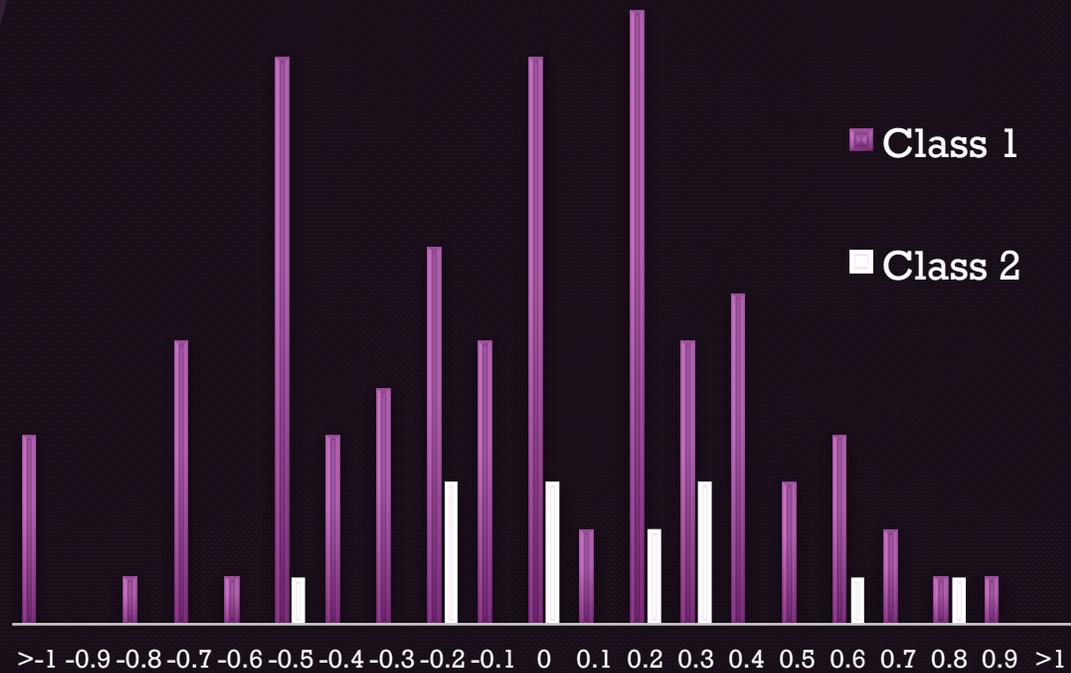
- ✧ Completed both
- ✧ 18+ years
- ✧ Spent  $\geq 10$ min on both
  
- ✧ Leaves ~55%:
  - ✧ 102 in class 1
  - ✧ 14 in class 2

- ◇ Motivation
- ◇ Study Basics
- ◇ Preliminary Results
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 University of Arizona  
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# Preliminary Results

## Normalized Gain Scores



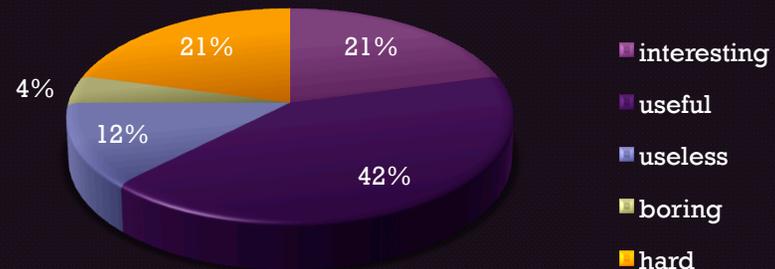
Class 1 : 64% pre, 64% post  
 Class 2: 68% pre, 73% post

# Math is....

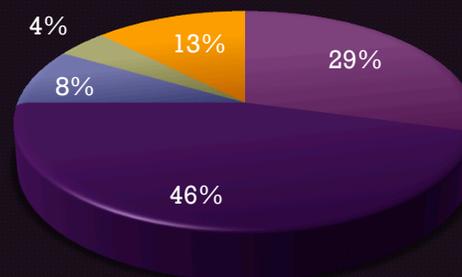
- ◇ Motivation
- ◇ Study Basics
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University of  
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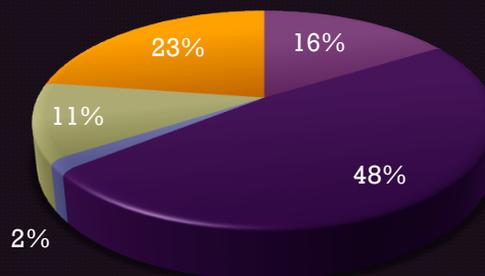
### Class 2 Pre



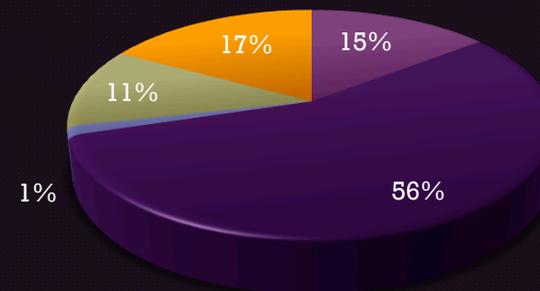
### Class 2 Post



### Class 1 Pre



### Class 1 Post



Spring, 2012

- ◇ Motivation
- ◇ Study Basics
- ◇ Preliminary Results
- ◇ Implications and Future Plans

- 6 classes
  - 4 small (25-35)
  - 1 large (100)
  - 1 very large (800+)
- 1000+ students
- Large research university + community college

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University of  
Arizona  
NNN 2012  
October 13, 2012

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

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University of  
Arizona  
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# Step 1: Data Analysis

- ✧ NSF TUES
- ✧ Survey development
- ✧ Curriculum development
- ✧ Instructor training

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

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University of  
Arizona  
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## Step 2: Skills Validation ✧

### Skills Survey

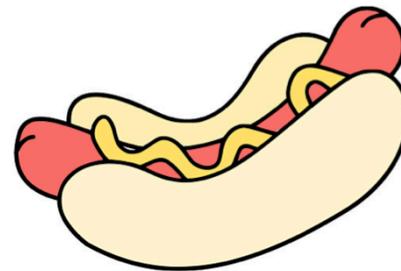
- ✧ Area and Volume
- ✧ Calculus (Integrals, Derivatives, Differential Eqns)
- ✧ Dimensional Analysis\* and Unit Conversions
- ✧ Elementary Algebra
- ✧ Error, Precision, Accuracy
- ✧ Estimation
- ✧ Exponents and Logarithms
- ✧ Geometry and Trigonometry
- ✧ Interpret Graphs (read, extrapolate, etc.)
- ✧ Linear and Exponential Growth
- ✧ Measurement and Units
- ✧ Percent and Percent Change
- ✧ Plotting/Making Graphs
- ✧ Probability, Odds, Risk
- ✧ Proportionality/Scaling and Relative Size/Scale
- ✧ Ratios, Fractions, Decimals
- ✧ Scientific Notation
- ✧ Significant Figures
- ✧ Simple Operations (+/-/×/÷)
- ✧ Statistics (mean, median, mode, standard deviation)
- ✧ Systems of Equations

- ◇ Motivation
- ◇ Study Basics
- ◇ Preliminary Results
- ◇ Implications and Future Plans

## Step 3: Curriculum

Kate Follette  
University of  
Arizona  
NNN 2012  
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Estimate how many hot dogs are served during an entire season of major league baseball.



- ◇ Motivation
- ◇ Study Basics
- ◇ Preliminary Results
- ◇ Implications and Future Plans

## Step 3: Curriculum

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University of  
Arizona  
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### Weeklong Challenge Question

Estimate how many planets with intelligent life exist in the universe.



- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

## Example: "Empty or crowded?" Think-Pair-Share question

- ✧ Based on the following information, which environment do you think is more crowded, the Solar System or the space between galaxies?
- ✧ How many Earths would fit between the Sun and Earth?
  - ✧ The distance between the Sun and Earth is  $1.5 \times 10^8$  km. The diameter of the Earth is  $1.3 \times 10^4$  km.
- ✧ How many galaxies would fit between the Milky Way and Andromeda?
  - ✧ The distance between the Milky Way and Andromeda is about two million light-years. The diameter of the Milky Way is about 100,000 light-years.

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

## Followup question and concept

- ✧ How many Suns would fit between the Sun and the next nearest star?
  - ✧ The light travel time across the Sun is  $\sim 4$  seconds.
  - ✧ The distance to alpha Centauri is  $\sim 4$  light-years.
- ✧ The Milky Way and Andromeda galaxies will collide in a few billion years. Do you expect their stars to collide?

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

# Lecture Tutorial Style Skill Activities

- ✧ Graph Interpretation
- ✧ Powers of Ten
- ✧ Scientific Notation
- ✧ Unit Conversions
- ✧ Dimensional Analysis
- ✧ Fractions and Percentages
- ✧ Ratios
- ✧ Scale Factors

Kate Follette  
University of  
Arizona  
NNN 2012  
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# Step 4: Faculty Training and Awareness

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

- ✧ Astronomical Society of the Pacific, 2011
  - ✧ Highlighted poster
  - ✧ Contributed article to Mercury Magazine
- ✧ American Astronomical Society 2012
- ✧ Astronomical Society of the Pacific, 2012
  - ✧ Panel Discussion
  - ✧ 1hr workshop
- ✧ American Astronomical Society
  - ✧ 2hr workshop

Kate Follette  
University of  
Arizona  
NNN 2012  
October 13, 2012

# Summary

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

- ✧ Innumeracy has serious implications for science literacy, and students' ability to spot pseudoscience in particular
- ✧ Intro science courses for non-majors captures an important innumerate demographic
- ✧ It is possible to change attitudes!
- ✧ It may be possible to improve skills, provoke awareness of need to improve

# THANK YOU!

- ✧ Motivation
- ✧ Study Basics
- ✧ Preliminary Results
- ✧ Implications and Future Plans

[kfollette@as.arizona.edu](mailto:kfollette@as.arizona.edu)

[www.katefollette.com/QL](http://www.katefollette.com/QL)

Kate Follette  
University of  
Arizona  
NNN 2012  
October 13, 2012