

Quantitative Reasoning:

A Program for Student Success

Eric Gaze , Bowdoin College
Ohio Math Initiative

Columbus, OH

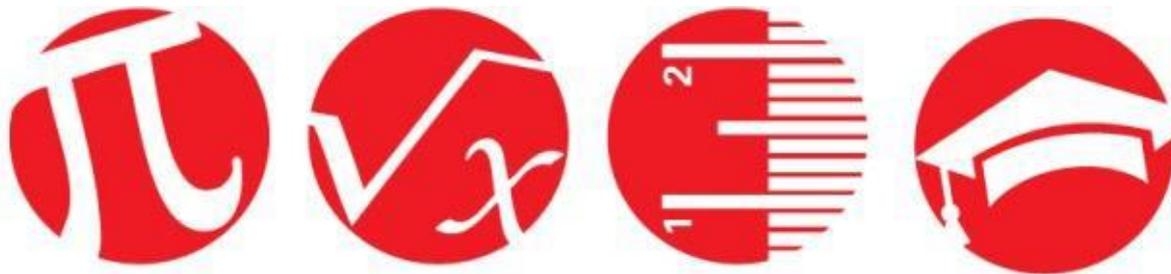
March 14, 2016

Outline:

- Why QR?
- QR Course:
 - Proportional Reasoning
 - Spreadsheets
- QL: Communicating with Numbers

Expectations for the Day:

- ▶ The purpose of today's faculty workshop is to learn about the basics of a QR course and effective pedagogy:
 - ▶ **Non-lecture Style**
 - ▶ **Group Work (IBL)**
 - ▶ **Written & Oral Communication**



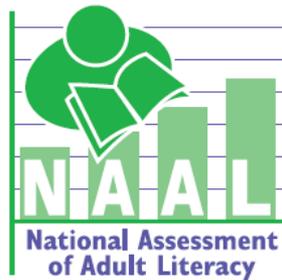
Ohio Mathematics Initiative

• *Re-envisioning Post-secondary Mathematics*

Why QR?

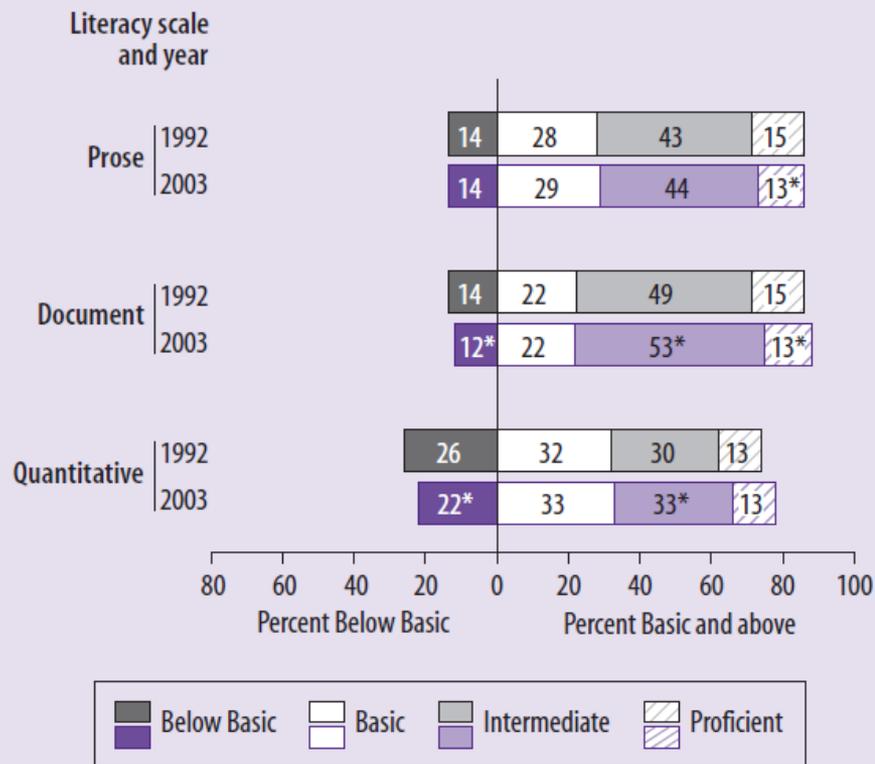
87% of U.S. Adults Cannot
Read or Write...

...With Numbers. They are
Quantitatively Illiterate.



U.S. Department of Education
NCES 2007-480

Figure 2-2. Percentage of adults in each prose, document, and quantitative literacy level: 1992 and 2003

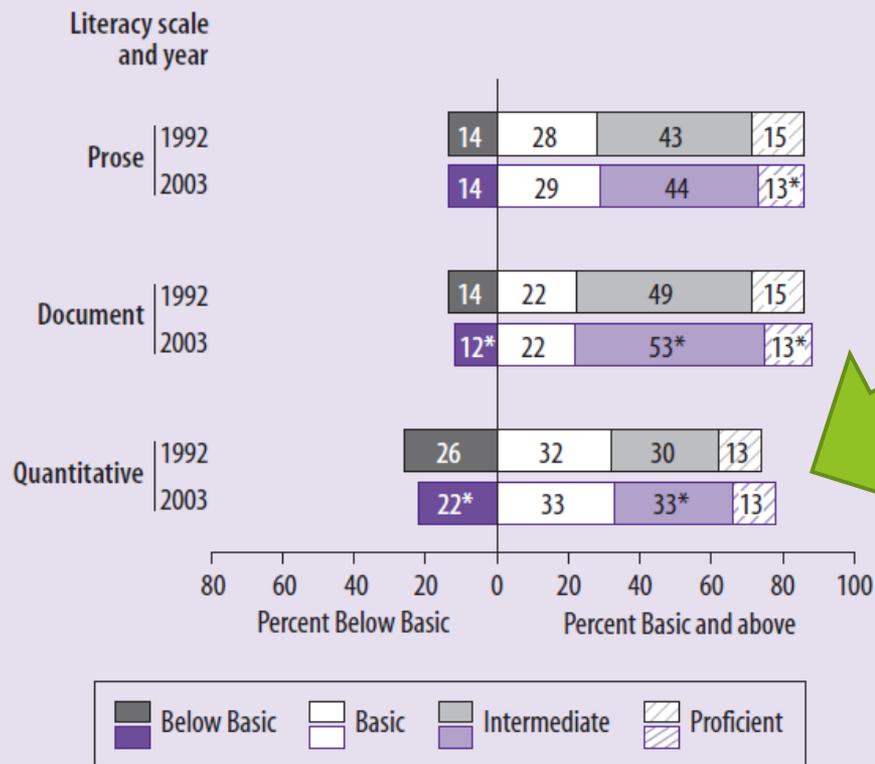


*Significantly different from 1992.

NOTE: Detail may not sum to totals because of rounding. Adults are defined as people 16 years of age and older living in households or prisons. Adults who could not be interviewed because of language spoken or cognitive or mental disabilities (3 percent in 2003 and 4 percent in 1992) are excluded from this figure.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 1992 National Adult Literacy Survey and 2003 National Assessment of Adult Literacy.

Figure 2-2. Percentage of adults in each prose, document, and quantitative literacy level: 1992 and 2003



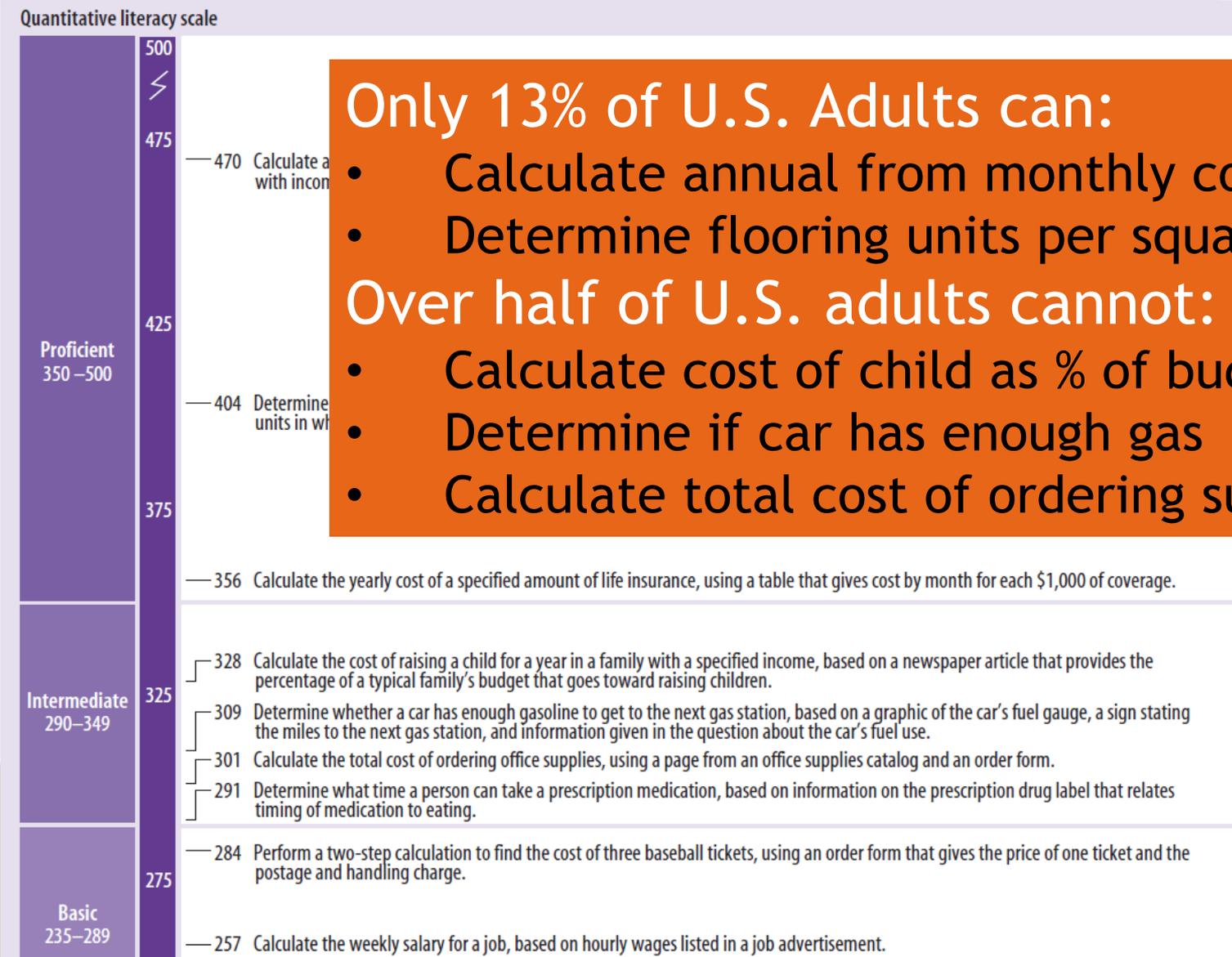
Only 13% U.S. Adults Proficient In QL

*Significantly different from 1992.

NOTE: Detail may not sum to totals because of rounding. Adults are defined as people 16 years of age and older living in households or prisons. Adults who could not be interviewed because of language spoken or cognitive or mental disabilities (3 percent in 2003 and 4 percent in 1992) are excluded from this figure.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 1992 National Adult Literacy Survey and 2003 National Assessment of Adult Literacy.

National Assessment of Adult Literacy: Proportional Reasoning



Only 13% of U.S. Adults can:

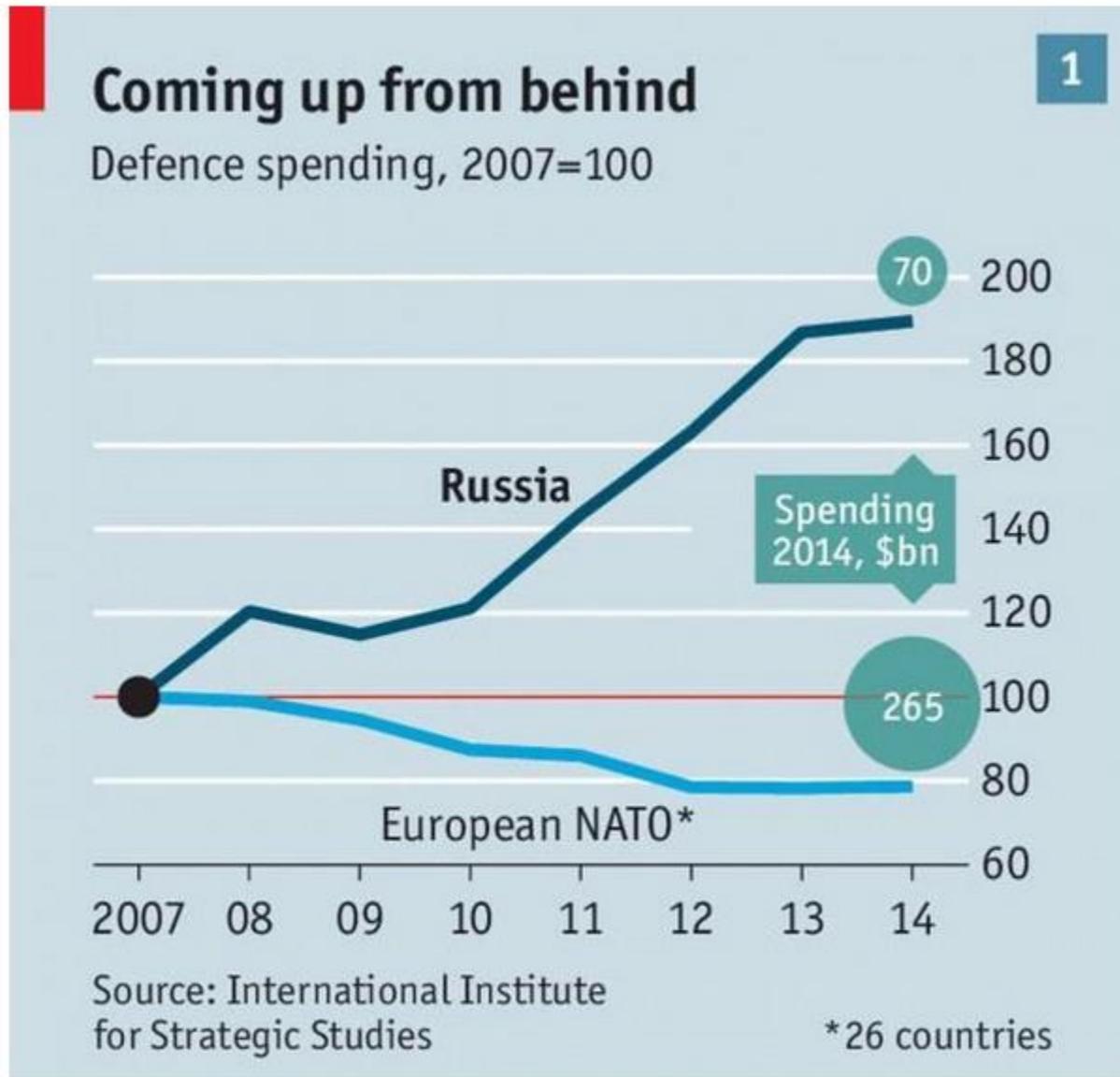
- Calculate annual from monthly costs
- Determine flooring units per square foot

Over half of U.S. adults cannot:

- Calculate cost of child as % of budget
- Determine if car has enough gas
- Calculate total cost of ordering supplies

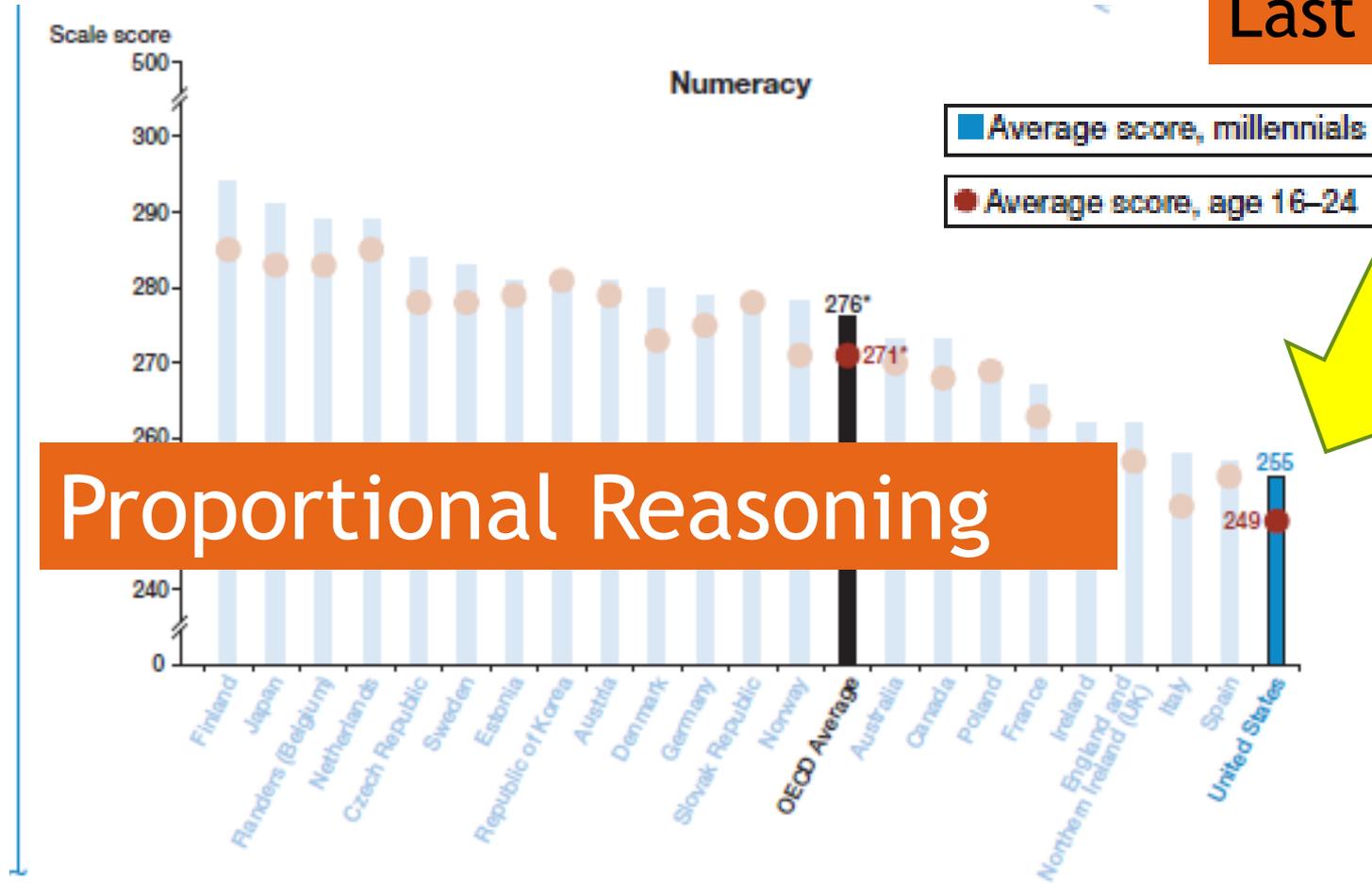
Worst Graph Ever...?

<http://www.washingtonpost.com/blogs/monkey-cage/wp/2015/02/16/not-the-worst-graph-ever/>



Current State of Affairs: Numeracy (OECD 2013 PIAAC)

U.S. is
Significantly
Last ($p < .05$)



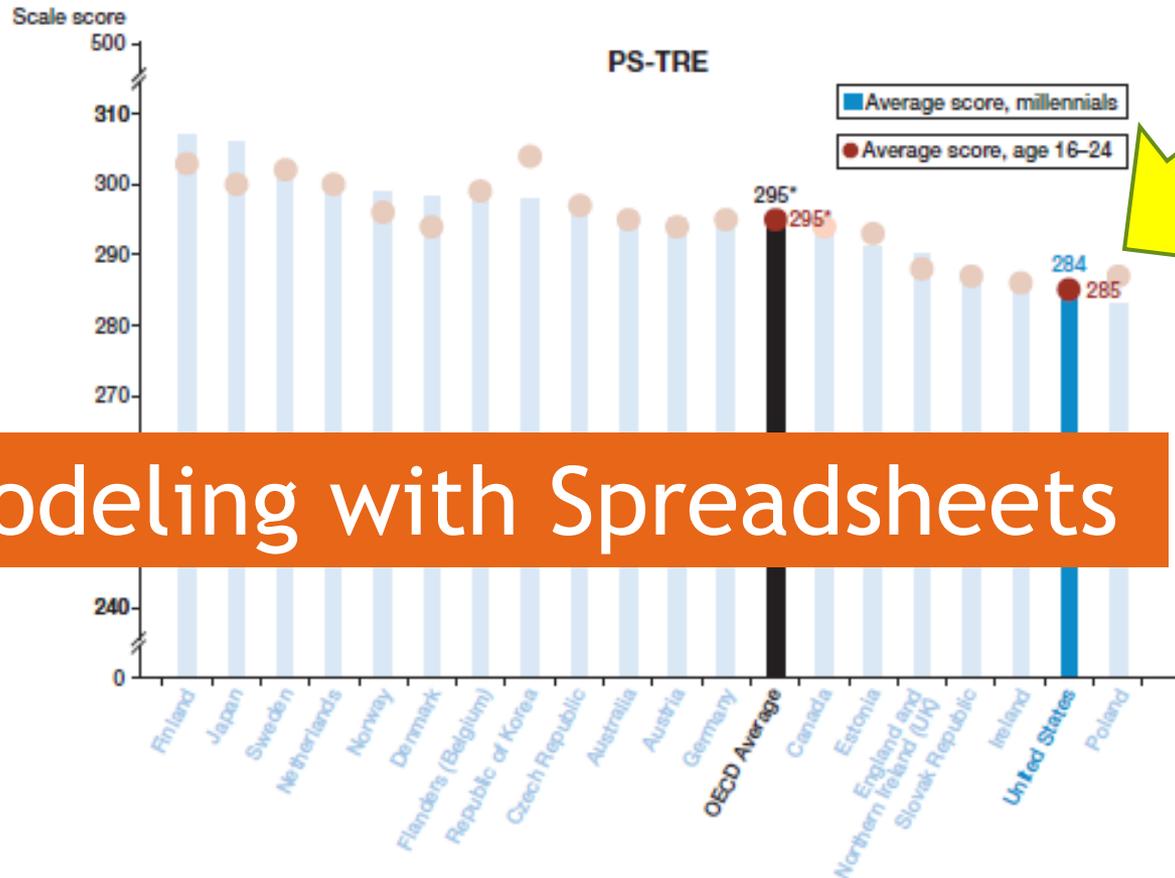
Proportional Reasoning

See notes at end of figure.

Current State of Affairs: Technology Problem Solving

U.S.
beat
Poland

Average scores on the PIAAC literacy, numeracy, and problem solving in technology-rich environments (PS-TRE) scales for adults age 16–34 (millennials) and adults age 16–24, by participating country/region: 2012—Continued



Modeling with Spreadsheets

* Significantly different ($p < .05$) from United States.

NOTE: The countries/regions are listed in descending order based on average scores for adults age 16–34 on the PIAAC literacy, numeracy, and problem solving in technology-rich environments scales. Please see appendix C-2 for complete data.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Programme for the International Assessment of Adult Competencies (PIAAC), 2012.

Quantitative Reasoning (QR):

Mathematics and Democracy (2001)

“Quantitative reasoning **empowers** people by giving them tools to think for themselves, to ask intelligent questions of experts, and to **confront authority confidently.**”

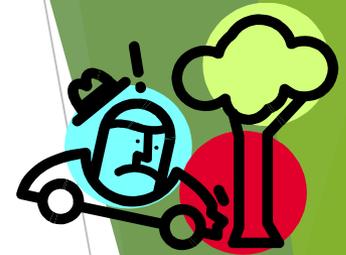
Thinking Quantitatively:

Communicating with Numbers

- ▶ How do we create a ~~mathematics~~ **QR curriculum** which teaches our students how to **THINK**?
- ▶ ***Thinking Quantitatively*** systematically develops fundamental proportional reasoning skills.
 - ▶ **Ratios** infused throughout using **spreadsheet** technology.

Proportional Reasoning

- ▶ Drunk drivers account for $\frac{1}{3}$ of all accidents...
 - ▶ So sober drivers are twice as dangerous?



Fraction of Accidents due to:	
Drunk Drivers	$\frac{1}{3}$
Sober Drivers	$\frac{2}{3}$

- ▶ 25-34 year olds get in 10 times as many accidents as 16 year olds...

	# accidents 2009:	# drivers:
16 year olds	229	1,000
25-34 year olds	89	1,000

Quantitative Literacy: Communicating (Reading and Writing) with Numbers NOT just Arithmetic and Algebra

Is Algebra Necessary?

- Andrew Hacker Professor Emeritus CUNY
New York Times July 29, 2012

“What is needed is **not textbook formulas** but greater understanding of where various numbers come from and what they actually convey.”



The Wrong Way to Teach Math

- Andrew Hacker Professor Emeritus CUNY
New York Times February 27, 2016

“Ours has become a quantitative century, and we must master its language. Decimals and ratios are now as crucial as nouns and verbs.”



<http://www.nytimes.com/2016/02/28/opinion/sunday/the-wrong-way-to-teach-math.html>

The Wrong Way to Teach Math

- Andrew Hacker Professor Emeritus CUNY
New York Times February 27, 2016

“The A.P. Statistics syllabus is practically a research seminar for dissertation candidates. Some typical assignments: **binomial random variables, least-square regression lines, pooled sample standard errors.** Many students fall by the wayside. It’s not just the difficulty of the classes.

They can’t see how such formulas connect with the lives they’ll be leading. **Fewer than a third** of those enrolled in 2015 got grades high enough to receive credit at selective colleges.”



Is Algebra Necessary?

Enrollments in Math Courses at Two-Year Colleges* (Enrollments in thousands)

	1990	1995	2000	2005	2010
Pre-College Level					
Pre-Algebra	45	91	87	137	226
Elementary Algebra (HS level)	262	304	292	380	428
Intermediate Algebra (HS level)	261	263	255	336	344
Pre-Calculus Level					
College Algebra	153	186	173	206	230
College Algebra + Trigonometry	18	17	16	14	11
Total All Math Courses	1,272	1,425	1,347	1,696	2,024
* CBMS 2013					

Over 2/3 of math courses at 2-year schools are some flavor of algebra!
College Algebra now being replaced with QR courses across the country.

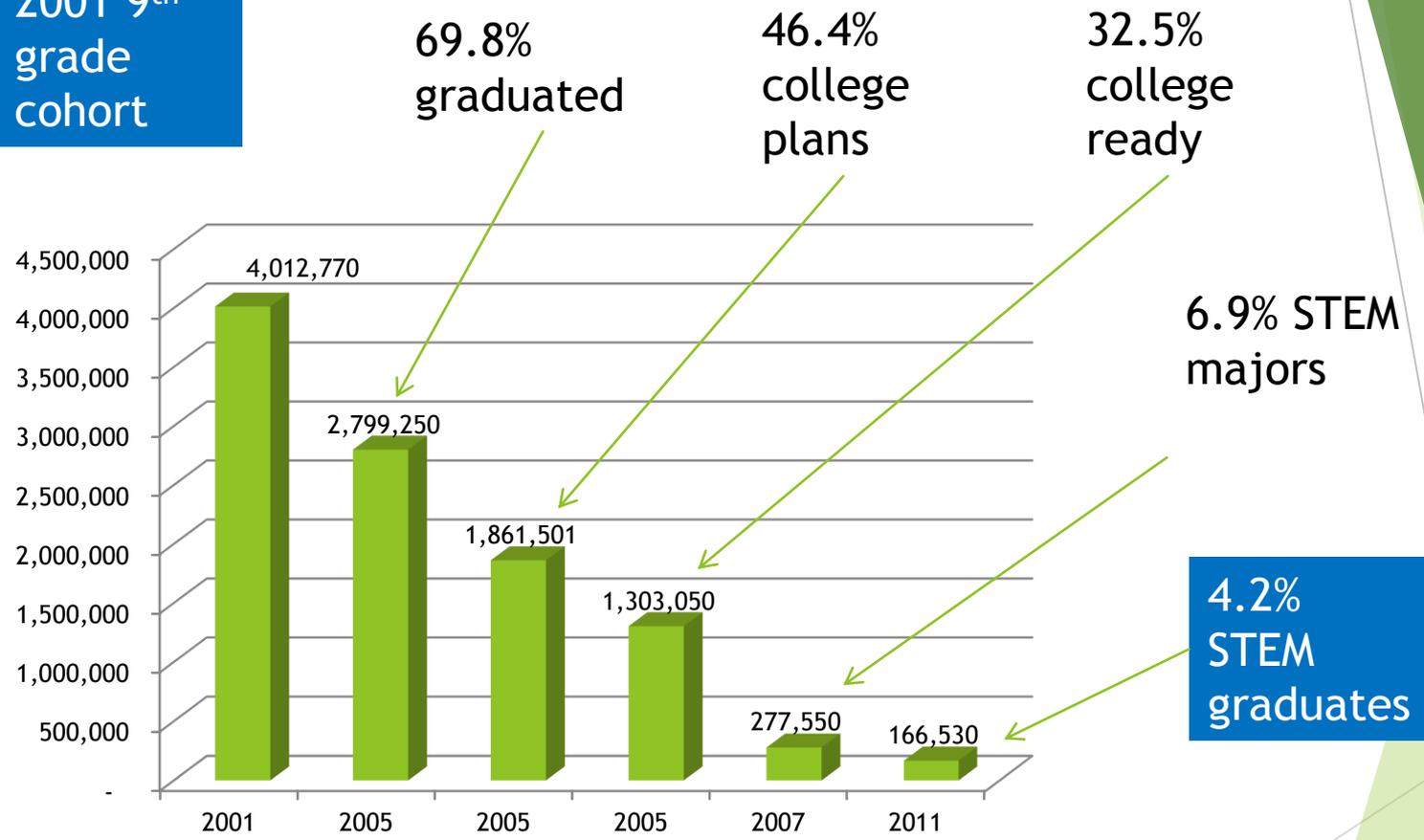
Conference Board of Mathematical Sciences 2010 Survey* (Enrollments in thousands)

	1995	2000	2005	2010
Two-year colleges				
Finite Math	24	19	22	18
Math for Liberal Arts (MLA)	38	43	59	91
Calculus I	58	53	51	65
Four-year colleges and universities				
Finite Math	59	82	94	62
Math for Liberal Arts (MLA)	74	86	123	147
Calculus I	192	192	201	235

MLA course enrollments more than doubled (113%)! Calculus I up only 20% over same period.

Who Really Needs Algebra?

2001 9th grade cohort



Thinking Quantitatively...

Math for Everyone Else!

How Much Math Do We Really Need?

- Professor Emeritus U. Ill. Chicago
Washington Post 10/22/2010

“Unlike literature, history, politics and music, math has **little relevance** to everyday life.”

“All the math one needs in real life can be **learned in early years** without much fuss.”

“Most adults have no contact with math at work, nor do they curl up with an **algebra** book for relaxation.”

Algebra as Business Math

Circa 1200 CE

“Few in business today make use of the mathematics they learned in school. **Spreadsheets** have entirely different requirements.”

“Mathematical reasoning in workplaces **differs markedly** from the algorithms taught in school.”

“Make no mistake; the revolution in business math created by the spreadsheet is conceptual as well as physical. **It changes the way people in business think** about and approach problems as well as the way they work through results. It enables them to quantify a **whole new range of problems.**”

Impatience with Irresolution

Sitcom Culture: Problems should not take more than 30 minutes, be easy to understand, and have a happy ending.

Algebra for Problem Solving?

▶ Well Structured Problems

- ▶ Objective Clear
- ▶ Assumptions Obvious
- ▶ Data available
- ▶ One right answer

▶ Examples:

- ▶ Solve $2x - 5/x = 12$ for x .
- ▶ Balance the books.
- ▶ Do your taxes.
 - ▶ Hopefully this is well structured!

▶ Ill Structured Problems

- ▶ Objectives, Assumptions, Data ambiguous

▶ Examples

- ▶ Should the Red Cross pay for blood donations?
- ▶ Should we tax soda?
- ▶ What data visualization should we make?
- ▶ Should you buy a Prius or a Focus?

Tolerance for Ambiguity

Problem Solving and Modeling

-Modeling for Insight

Powell and Batt

- ▶ Ill Structured Problems are **Explored**
 - ▶ Make assumptions
 - ▶ Formulate Hypotheses
 - ▶ Generate Insights (don't "solve!")

- ▶ Modeling Process
 - ▶ Frame the Problem
 - ▶ Diagram the Problem
 - ▶ Influence Diagrams (relationships between variables)
 - ▶ Build a Model
 - ▶ **Spreadsheet Engineering/** Parametrization
 - ▶ Sensitivity/ Strategy Analysis
 - ▶ Generate Insights
 - ▶ Iterate!

N Ways to Apply Algebra with the New York Times

-Patrick Honner

September 26, 2012

- ▶ Amortization schedules
 - ▶ Buy versus Rent Scenario

▶ Evaluating Colleges

- ▶ “Use data from schools.”

▶ Calculating

- ▶ “Create a

▶ Metro Card

- ▶ Unlimited

▶ Olympic Algebra

- ▶ “Compare events, and

▶ Stock Portfolio

- ▶ Compound interest formula, exponential growth, and compare different rates of return.

Modeling Process

Frame the Problem

Diagram the Problem

Influence Diagrams (relationships between variables)

Build a Model

Spreadsheet Engineering/ Parametrization

Sensitivity/ Strategy Analysis

Generate Insights

Iterate!

The Right Way to Teach Math

- Keith Devlin February 29, 2016

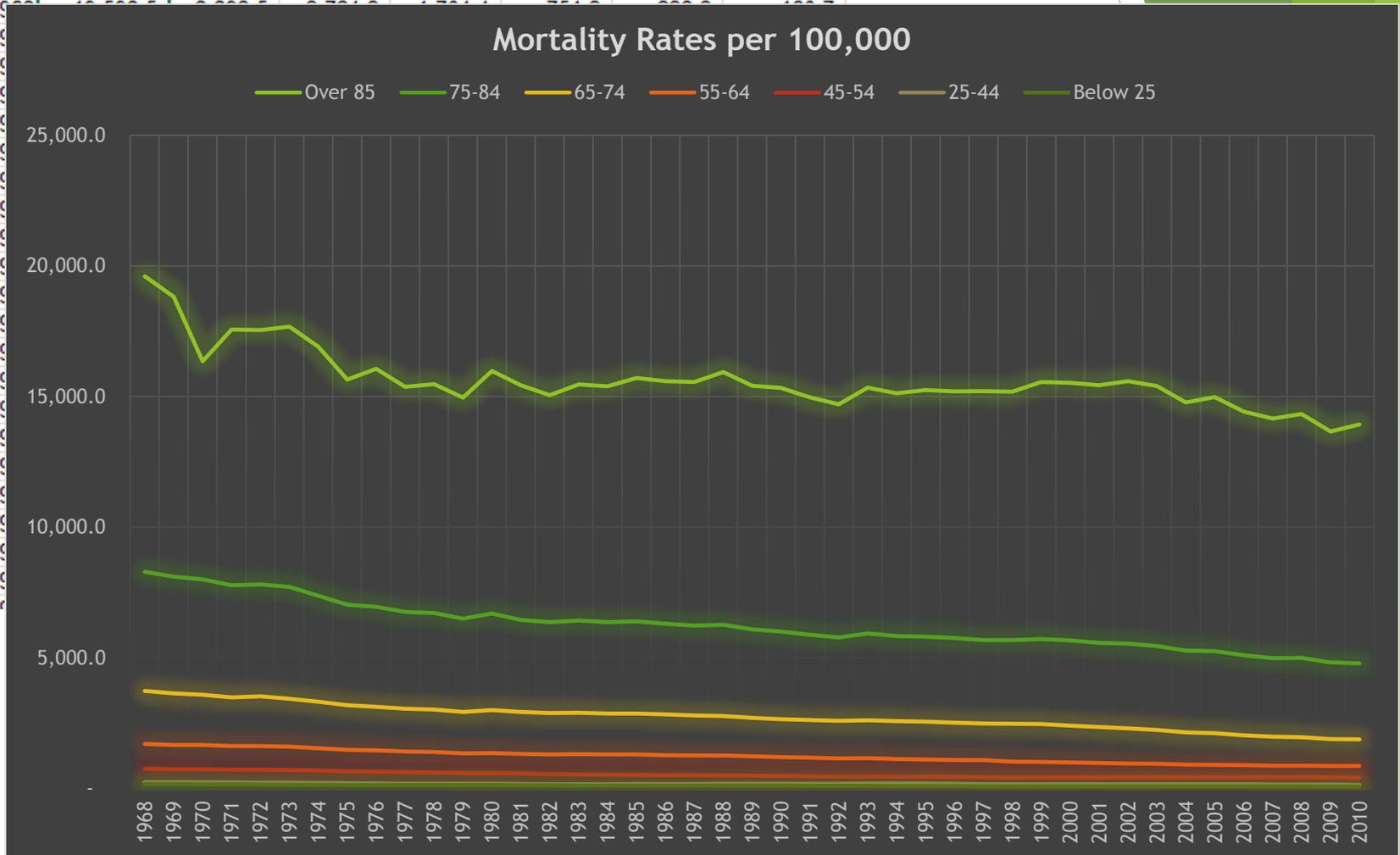
“For there is a much more recent implementation of al-Khwarizmi's method of algebra--one of immediate use to everyone in today's world: the **electronic spreadsheet**. A perfectly correct description of Microsoft Excel is that it is a computer implementation of algebra...”



- http://www.huffingtonpost.com/dr-keith-devlin/andrew-hacker-and-the-cas_b_9339554.html

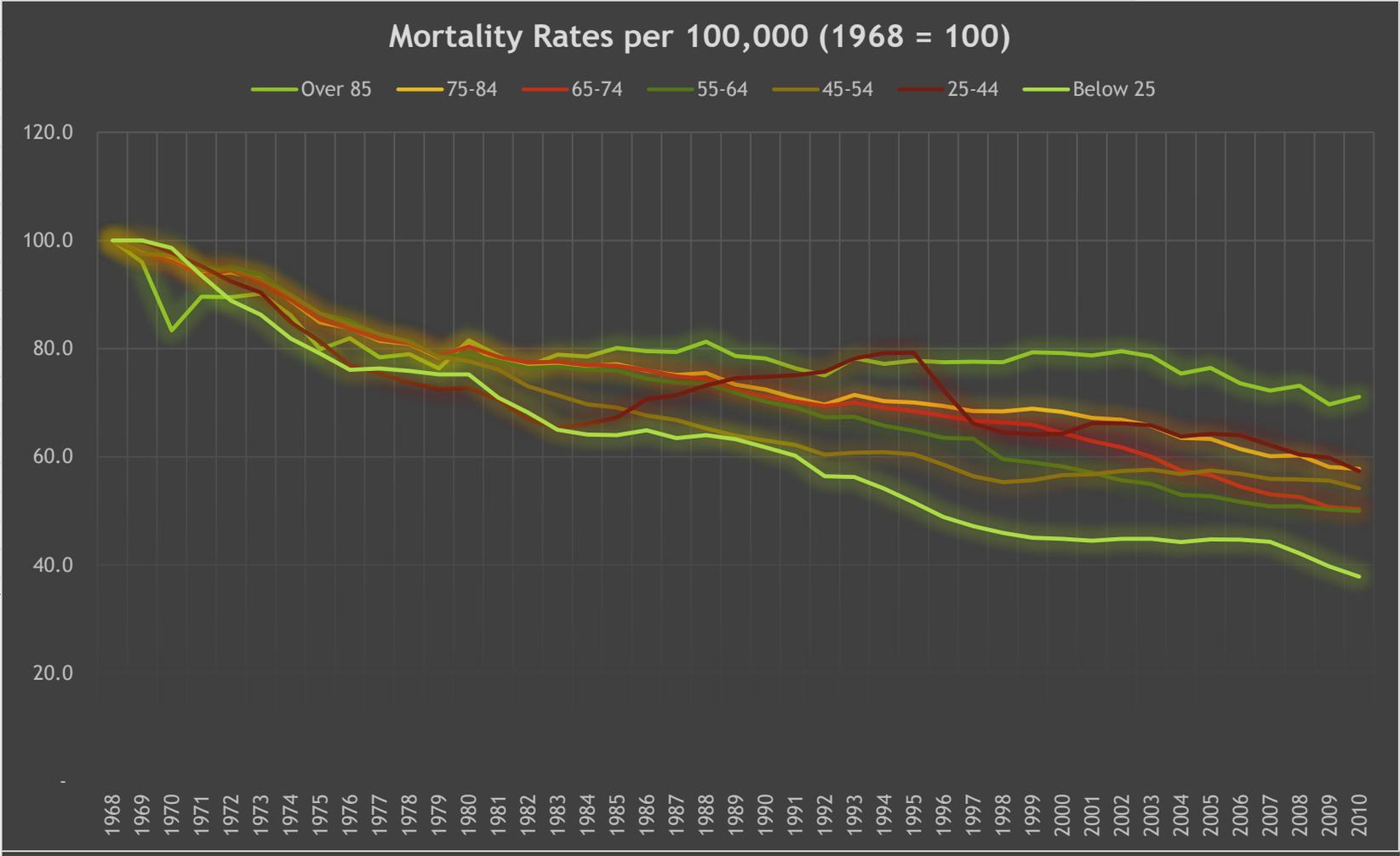
Working with Data: Proportional Reasoning in Action!

	A	B	C	D	E	F	G	H
1	Year	Mortality Rate per 100,000						
2		Over 85	75-84	65-74	55-64	45-54	25-44	Below 25
3	1968	19,500.0	8,500.0	4,000.0	3,000.0	2,500.0	2,000.0	1,500.0
4	1969	19,000.0	8,200.0	3,800.0	2,800.0	2,300.0	1,900.0	1,400.0
5	1970	16,500.0	8,000.0	3,600.0	2,700.0	2,200.0	1,800.0	1,300.0
6	1971	17,500.0	7,800.0	3,500.0	2,600.0	2,100.0	1,700.0	1,200.0
7	1972	17,500.0	7,800.0	3,500.0	2,600.0	2,100.0	1,700.0	1,200.0
8	1973	17,500.0	7,800.0	3,500.0	2,600.0	2,100.0	1,700.0	1,200.0
9	1974	17,000.0	7,600.0	3,400.0	2,500.0	2,000.0	1,600.0	1,100.0
10	1975	15,500.0	7,400.0	3,300.0	2,400.0	1,900.0	1,500.0	1,000.0
11	1976	16,000.0	7,200.0	3,200.0	2,300.0	1,800.0	1,400.0	900.0
12	1977	15,500.0	7,000.0	3,100.0	2,200.0	1,700.0	1,300.0	800.0
13	1978	15,500.0	6,800.0	3,000.0	2,100.0	1,600.0	1,200.0	700.0
14	1979	15,000.0	6,600.0	2,900.0	2,000.0	1,500.0	1,100.0	600.0
15	1980	16,000.0	6,400.0	2,800.0	1,900.0	1,400.0	1,000.0	500.0
16	1981	15,500.0	6,200.0	2,700.0	1,800.0	1,300.0	900.0	400.0
17	1982	15,000.0	6,000.0	2,600.0	1,700.0	1,200.0	800.0	300.0
18	1983	15,500.0	5,800.0	2,500.0	1,600.0	1,100.0	700.0	200.0
19	1984	15,500.0	5,600.0	2,400.0	1,500.0	1,000.0	600.0	100.0
20	1985	15,800.0	5,400.0	2,300.0	1,400.0	900.0	500.0	0.0
21	1986	15,500.0	5,200.0	2,200.0	1,300.0	800.0	400.0	0.0
22	1987	15,500.0	5,000.0	2,100.0	1,200.0	700.0	300.0	0.0
23	1988	16,000.0	4,800.0	2,000.0	1,100.0	600.0	200.0	0.0
24	1989	15,500.0	4,600.0	1,900.0	1,000.0	500.0	100.0	0.0
25	1990	15,500.0	4,400.0	1,800.0	900.0	400.0	0.0	0.0
26	1991	15,000.0	4,200.0	1,700.0	800.0	300.0	0.0	0.0
27	1992	14,800.0	4,000.0	1,600.0	700.0	200.0	0.0	0.0
28	1993	15,500.0	3,800.0	1,500.0	600.0	100.0	0.0	0.0
29	1994	15,000.0	3,600.0	1,400.0	500.0	0.0	0.0	0.0
30	1995	15,200.0	3,400.0	1,300.0	400.0	0.0	0.0	0.0
31	1996	15,200.0	3,200.0	1,200.0	300.0	0.0	0.0	0.0
32	1997	15,200.0	3,000.0	1,100.0	200.0	0.0	0.0	0.0
33	1998	15,200.0	2,800.0	1,000.0	100.0	0.0	0.0	0.0
34	1999	15,500.0	2,600.0	900.0	0.0	0.0	0.0	0.0
35	2000	15,500.0	2,400.0	800.0	0.0	0.0	0.0	0.0
36	2001	15,500.0	2,200.0	700.0	0.0	0.0	0.0	0.0
37	2002	15,500.0	2,000.0	600.0	0.0	0.0	0.0	0.0
38	2003	15,500.0	1,800.0	500.0	0.0	0.0	0.0	0.0
39	2004	14,800.0	1,600.0	400.0	0.0	0.0	0.0	0.0
40	2005	15,000.0	1,400.0	300.0	0.0	0.0	0.0	0.0
41	2006	14,500.0	1,200.0	200.0	0.0	0.0	0.0	0.0
42	2007	14,200.0	1,000.0	100.0	0.0	0.0	0.0	0.0
43	2008	14,500.0	900.0	0.0	0.0	0.0	0.0	0.0
44	2009	13,800.0	800.0	0.0	0.0	0.0	0.0	0.0
45	2010	14,000.0	700.0	0.0	0.0	0.0	0.0	0.0



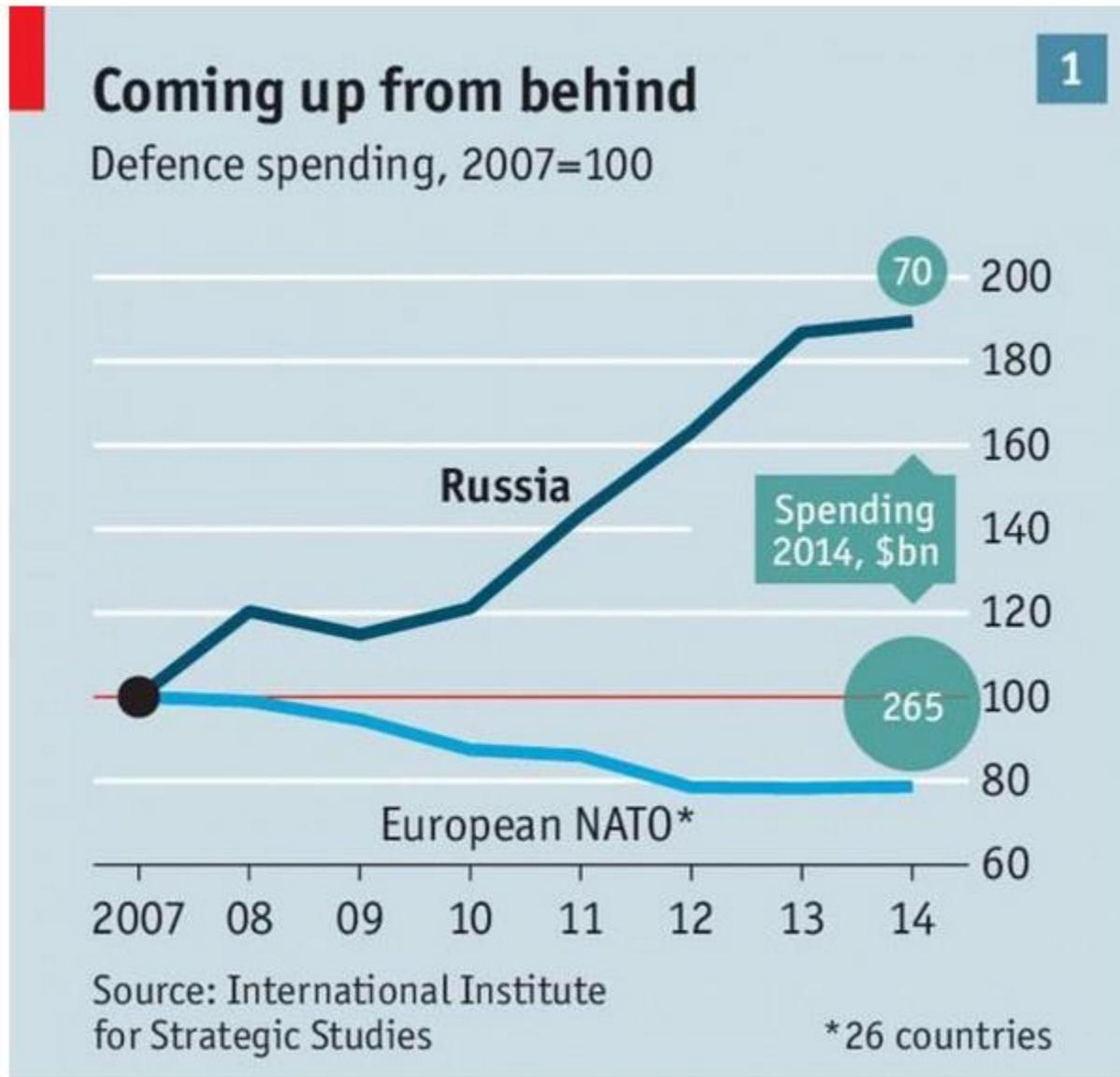
Working with Data: Proportional Reasoning in Action!

	K	L	M	N	O	P	Q	R
1	Year							
2		Over 85	75-84	65-74	55-64	45-54	25-44	Below 25
3	1968	100.0	100.0	100.0	100.0	100.0	100.0	100.0



Worst Graph Ever...?

<http://www.washingtonpost.com/blogs/monkey-cage/wp/2015/02/16/not-the-worst-graph-ever/>



Modeling Car Cost: Proportional Reasoning in Action!

	Focus	Prius		
Cost	\$ 20,000.00	\$ 33,000.00		
			Gallons per 100 miles	
MPG Hway	28	45	3.571	2.222
MPG City	22	37	4.545	2.703
			Gallons Used	
Miles Hway	8,000		285.71	177.78
Miles City	12,000		545.45	324.32
Price per Gallon	\$ 3.86	Total Gallons	831.17	502.10
		Cost:	\$ 3,208.31	\$ 1,938.11
		Gas Savings per year:	\$ 1,270.20	
		Extra Cost:	\$ 13,000.00	
		Years to recoup:	10.23 years	

Modeling Car Cost

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Price per Gallon	\$ 3.86	Total Gallons	831.17	502.10
		Cost:	\$ 3,208.31	\$ 1,938.11
	Gas Savings per year:		\$ 1,270.20	
		Extra Cost:	\$ 13,000.00	
	Years to recoup:		10.23	years

Which parameter has the greatest impact on the years to recoup extra cost of the Prius?

1. Cost of Prius
2. MPG City Focus
3. Cost of Focus
4. MPG City Prius

Is Algebra Necessary?

Yes! And we can use spreadsheets and modeling to help teach students why.

Handouts have more examples 😊

Counting 1, 2, 3,...

▶ They Counted What?

▶ Centenarians?

▶ 1970: 106,4

▶ 1980: 32,1

▶ 2010: 53,3

▶ Homeless?

▶ 1980: 3,000,000

▶ Who is “homeless”?

▶ Student Loan Default Rates Rise Sharply in Past Year

▶ 8.8% of all borrowers defaulted in the past year ending Sept. 30, up from 7%...

▶ What does “default” mean?

▶ 2 year default rate

▶ Only 37% have paid back on time since 2005

Damned Lies and Statistics: The Social Construction of Statistics by Joel Best

1. Who created this statistic?

2. Why was this statistic created?

3. How was this statistic created?

Counting 1, 2, 3,...

- ▶ How big is that?
 - ▶ Keen sense of proportion... RATIOS!
 - ▶ Anorexia Deaths: 150,000 (1994)
 - ▶ Mutant Statistic: only 55,500 women 15-44 died that year!
- ▶ US Household Debt
 - ▶ Record \$13.8 trillion in 2011
- ▶ Is that a BIG number?
 - ▶ ~\$46,000 per person
 - ▶ \$884/week per person for 1 year (using \$15.6 billion as a yardstick)

“41.1% of blacks were arrested in 1997, which means 7.4 out of every 1,000 people was a violent black criminal...”

Really? So 56.8% of whites were arrested for violent crimes as well?...

Black and White Victimization's and Arrests for Crimes of Violence 1997

	Number	Percent	Rate
Victimization			
White	7,068,590	82.1	37.1
Black	1,306,810	15.2	46.8
Arrests			
White	284,523	56.8	1.5
Black	205,823	41.1	7.4

Quantitative **Literacy**: Communicating (Reading and Writing) with Numbers NOT just Arithmetic

What's the Chance of That?

- ▶ One slice of bacon a day increases risk of colorectal cancer in men by 21%
 - ▶ For every alcoholic drink a woman consumes her risk of breast cancer **\$1.00 increases to \$1.05 is clearly a 5% increase**
 - ▶ **Oops!** Risk of breast cancer increases by 6% for every extra alcoholic drink consumed on a daily basis **1% increases to 6% is clearly NOT a 5% increase.**
 - ▶ Where did we start?
- ▶ Start: 5 in 100 men get colorectal cancer in their lifetime.
 - ▶ Add bacon every day and about 6 out of 100 would.
- ▶ Start: 9 in 100 women will get breast cancer in their lifetime.
 - ▶ Add 2 drinks a day and about 10 in a 100 would.



“In other words, translating a ratio to a percentage is not just a mathematical operation, but also a rhetorical practice in which artistic appeals are manipulated.”
- Joanna Wolfe

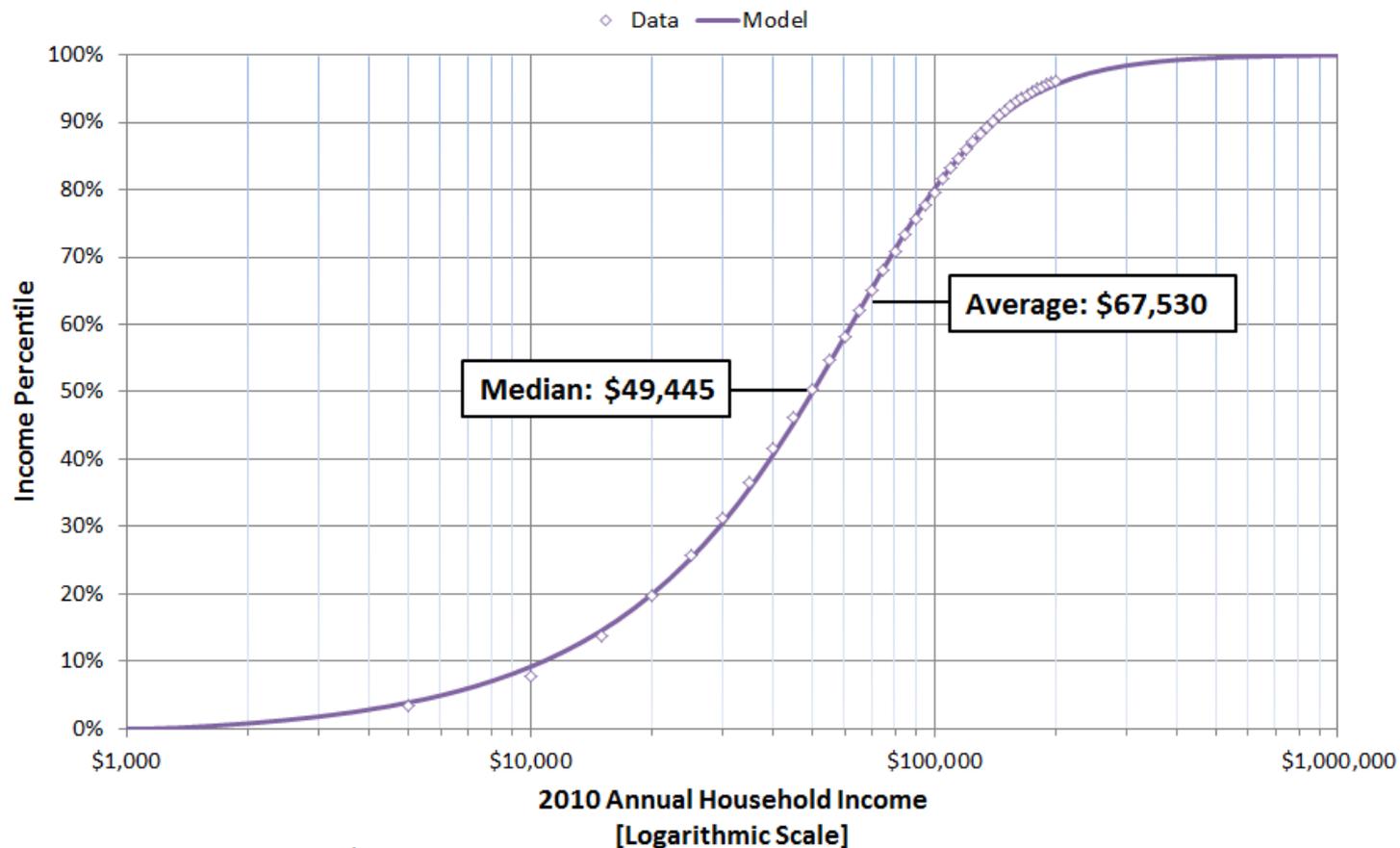
- ▶ Women are 68% percent more likely than men to experience depression in their lifetimes.
- ▶ Over 75% of women never experience depression in their lifetime.
- ▶ 17.1 percent of individuals have experienced depression in their lifetime.
- ▶ Over 1 in 5 women and 1 in 8 men have experienced depression in their lifetimes.
- ▶ Approximately four of every ten depressed individuals is a man.

Statistics: 21.3% of women and 12.7% of men have experienced depression in their lifetime.

How Average...

► Statistical Literacy:

**Cumulative Distribution of Total Money Income Earned by Households
in the United States in 2010**



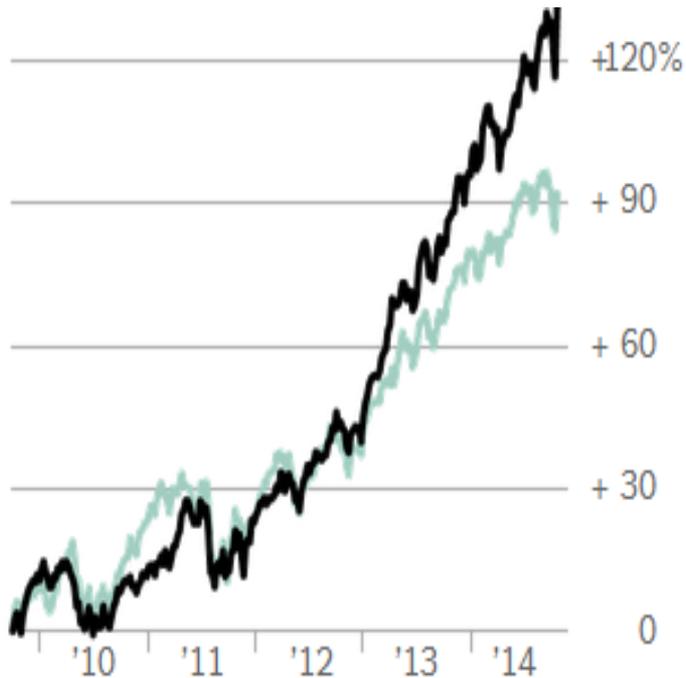
Source: U.S. Census Bureau, Current Population Survey, 2011
Annual Social and Economic Supplement, Table HINC-01

© Political Calculations 2011

Informed Citizenship

Is the Affordable Health Care Act Working?

- ▶ Health Care Companies are doing well:



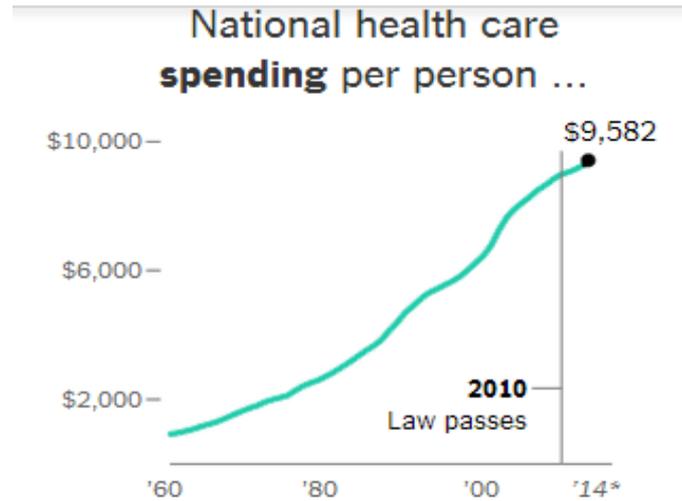
The S.& P. 500 health care index (—) has beaten the S.& P. 500-stock (—) index since last year ...

... and most health care companies have posted healthy profits so far this year.

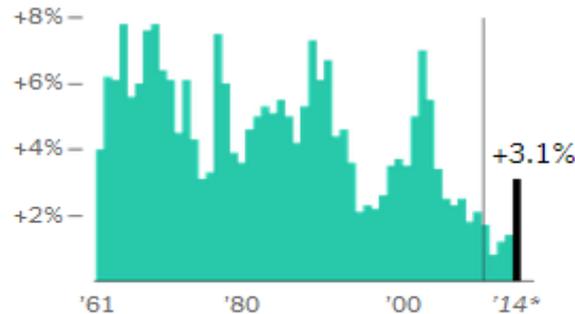
Informed Citizenship

Is the Affordable Health Care Act Working?

- ▶ Health Care Costs are skyrocketing but growth is slowing?



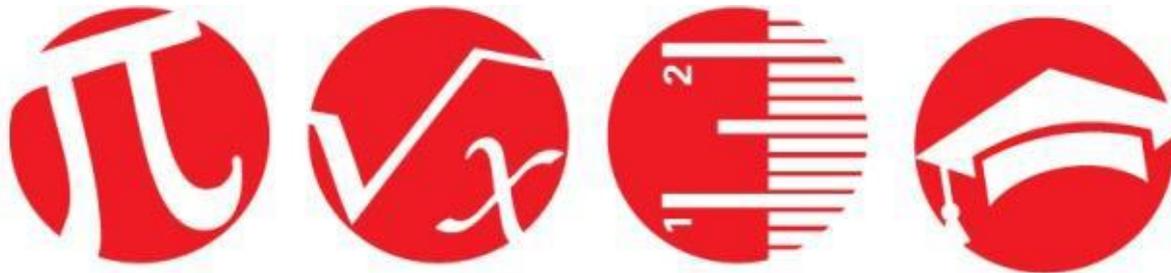
... and the **change** from the previous year.



*Projection. Note: Figures are adjusted for inflation.

Ohio Transfer Module QR Course (TMM011) Learning Outcomes:

- ▶ **Numeracy**
- ▶ **Mathematical Modeling**
- ▶ **Probability and Statistics**



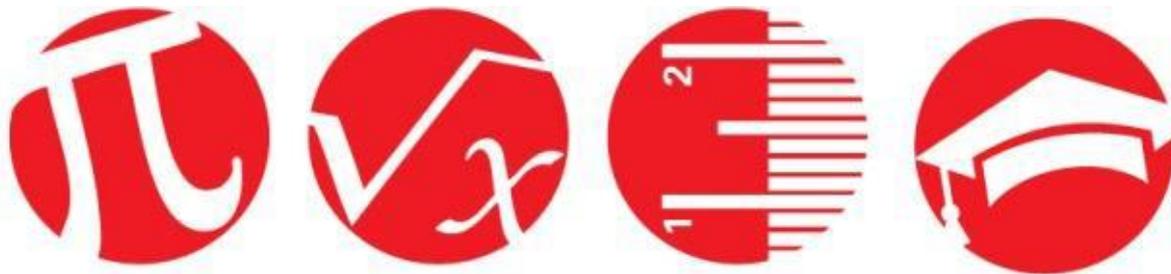
Ohio Mathematics Initiative

• *Re-envisioning Post-secondary Mathematics*

Numeracy:

Students will develop and use the concepts of numeracy to investigate and explain quantitative relationships and solve problems in a variety of real-world contexts.

- ▶ **Aaron Altose Cuyahoga Community College**



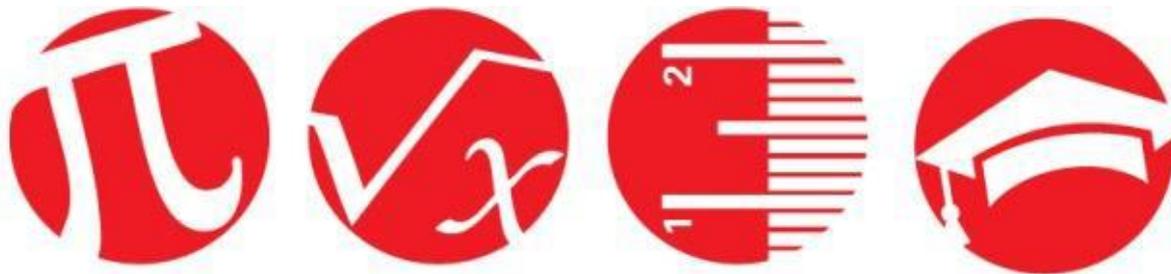
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Mathematical Modeling:

Students will make decisions by analyzing mathematical models, including situations in which the student must recognize and/or make assumptions.

► James Willis Sinclair College



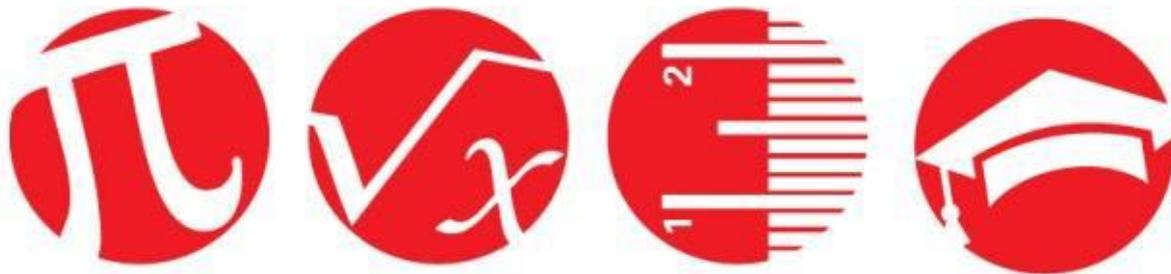
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Statistics and Probability:

Students will use the language and structure of statistics and probability to investigate, represent, make decisions, and draw conclusions from real-world contexts.

- ▶ **Ricardo Moena University of Cincinnati**



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Traditional Math Education vs QR

“When we live in a system, we absorb a system and think in a system.”

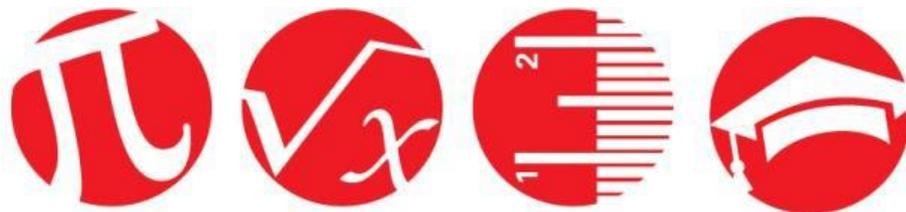
► James Douglass

REDUCTIONIST	WHOLISTIC (holistic)
Parable of the six blind men: What do you see? Pillar/branch/pipe/rope/fan/wall	
Constituent parts simplicity	Whole is greater than sum of parts complexity
Mathematics Education	
ARITHMETIC: Ratio/Rate/Percent/Fraction/Decimal	Proportional Reasoning
ALGEBRA: Linear/Rational/Quadratic/Roots/Factoring	Algebraic Reasoning
Problem Solving	
CONTRIVED Well Structured Problems	MESSY Ill Structured Problems

Effective Pedagogy?

“How to help students translate the particular problem they see in front of them into some “model” or concept; figure out what is known, what is unknown, what might be assumed, and then relate that to a formula that they are given.”

- ▶ **Solve for b: $a = b \times c$**
- ▶ **Solve for m: $F = m \times a$**
- ▶ **Transfer is difficult!**



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The QLR Assessment Project

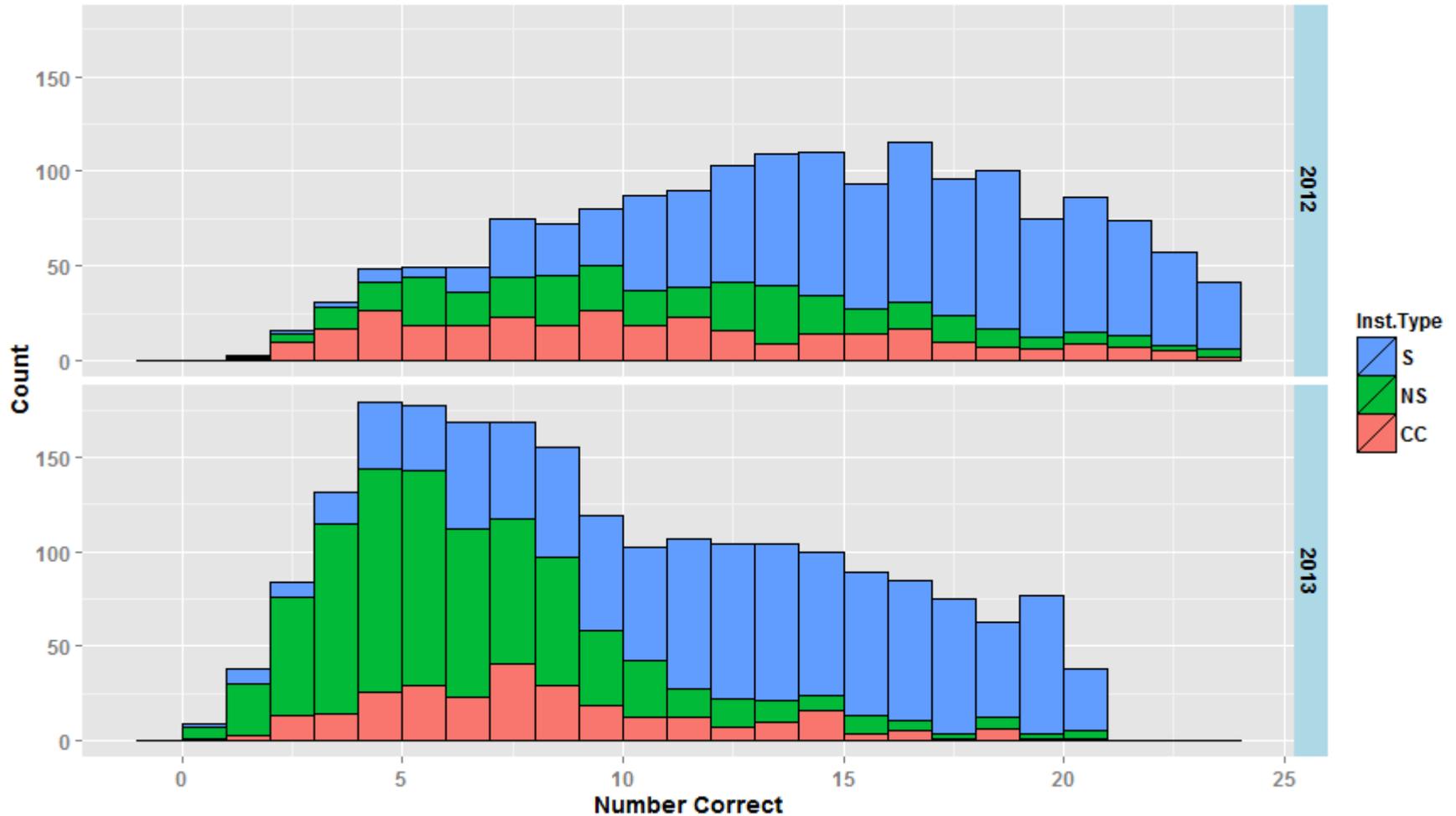


Institution Type	2012 Mean %	2012 Std. Dev.	2013 Mean %	2013 Std. Dev.
2-Year	44.7	23.4	39.3	20.2
Selective 4-year	66.4	20.0	59.7	22.8
Non-selective 4-year	47.2	21.6	30.1	17.9
Total	58.4	23.3	45.6	24.7

Note: the significant drop in mean score due to increase in non-selective school participation.

Institution Type	2012 N	2012 %	2013 N	2013 %
2-Year	314	18.9	273	12.6
Non-selective 4-year	334	20.1	811	37.3
Selective 4-year	1011	60.9	1088	50.1
Total	1659	100.0	2172	100.0

The QLR Assessment Project



Again you can see influence of non-selective school participation rates.



The Bowdoin QR Exam

- ▶ 30 question entrance exam used for advising
 - ▶ Under 50% on Bowdoin Q-exam criteria for Math 050 (N = 50)
- ▶ Significant predictor of GPA (N = 3,000)
 - ▶ Cumulative GPA $r = 0.39$
 - ▶ MCSR GPA $r = 0.48$
- ▶ Strongly correlated with 1st year Cum GPA $r = 0.48$
- ▶ Multivariate Regression Models ($R^2 = 0.30$ Cum GPA and $R^2 = 0.36$ MCSR GPA)



Th

Holding All Other Variables Constant		
	Q-score 30%	Q-score 80%
Cum GPA	3.2	3.5
MCSR GPA	2.7	3.5

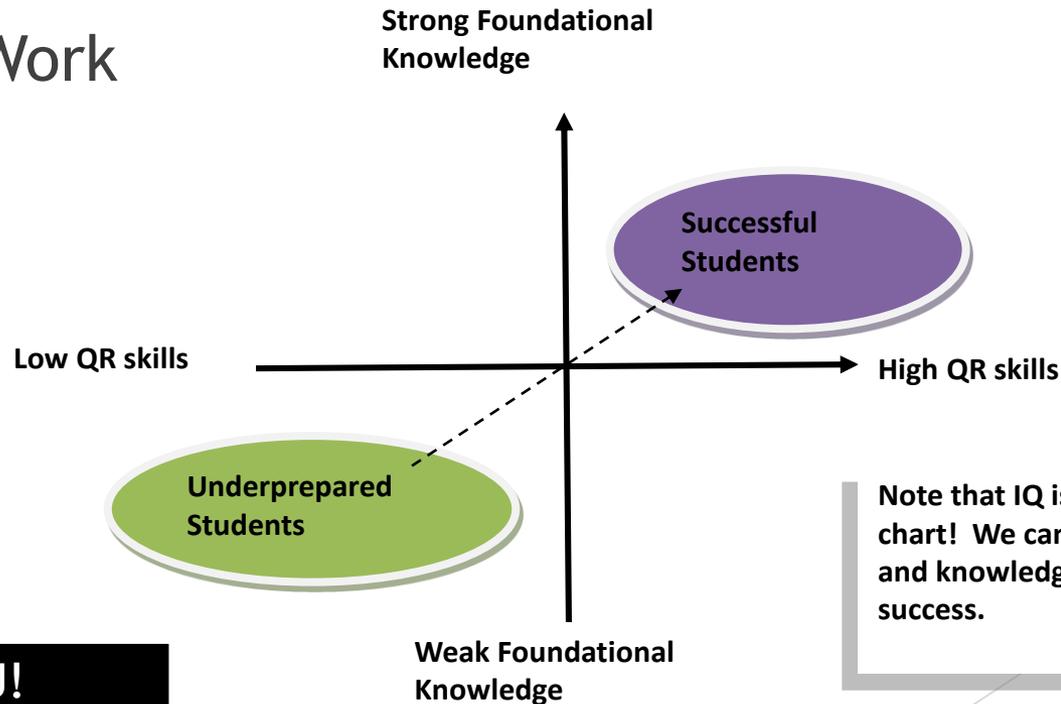
.30 Cum GPA

- ▶ These coefficients indicate the predicted difference in GPA associated with a 10 percentage point increase in respective aptitude test, with all other variables in model held constant.

Cumulative GPA Multivariate Regression Coefficients		
Math SAT	Q-score	Verbal SAT
0.0345	0.0603	0.0857
MCSR GPA Multivariate Regression Coefficients		
Math SAT	Q-score	Verbal SAT
0.1711	0.1599	0.0357

Scaffolding Student Success

- ▶ Math 1050: QR is an ENTRY point
- ▶ Math 1050: QR as a foundation for Calculus and Social Science
- ▶ Math 1050: QR is an EXIT point
- ▶ Future Work



THANK YOU!
Questions?