Quantifying measurement error from digital instruments

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What I’m doing

HELPING STUDENTS LEARN TO CONSTRUCT KNOWLEDGE

First lab: measurement error

Misconception: “Digital instruments have no ‘human error’”

Home glucose meters “glucometers”

FDA guidelines: within ±20%, 95% of the time.

- $140 \pm 30\ mg/dL$ (95% CL)
- Too many don’t even meet that requirement!

Excellent source of both random and systematic error!

STRIP SAFELY

Accurate Diabetes Testing Matters

Hacking Diabetes

#WeAreNotWaiting

Glucometer lab activities

Buy Dextrose (glucose) sweetener

- prepare 140 mg/dL aqueous soln.

Each group gets 50 test strips

- (ReliOn Prime from Walmart: $9)

Combine data "in the cloud"

- Individual spreadsheet calculations

Glucometer lab activities

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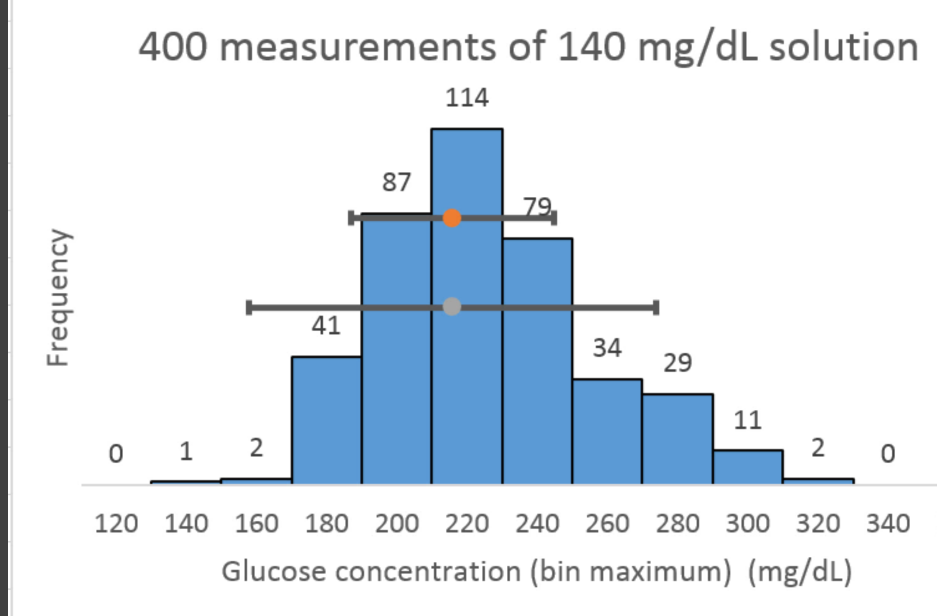
Combine data "in the cloud"
- Individual spreadsheet calculations
- Estimate standard deviation
- Working definition of σ
  - 68% within σ
  - 95% within 2 σ

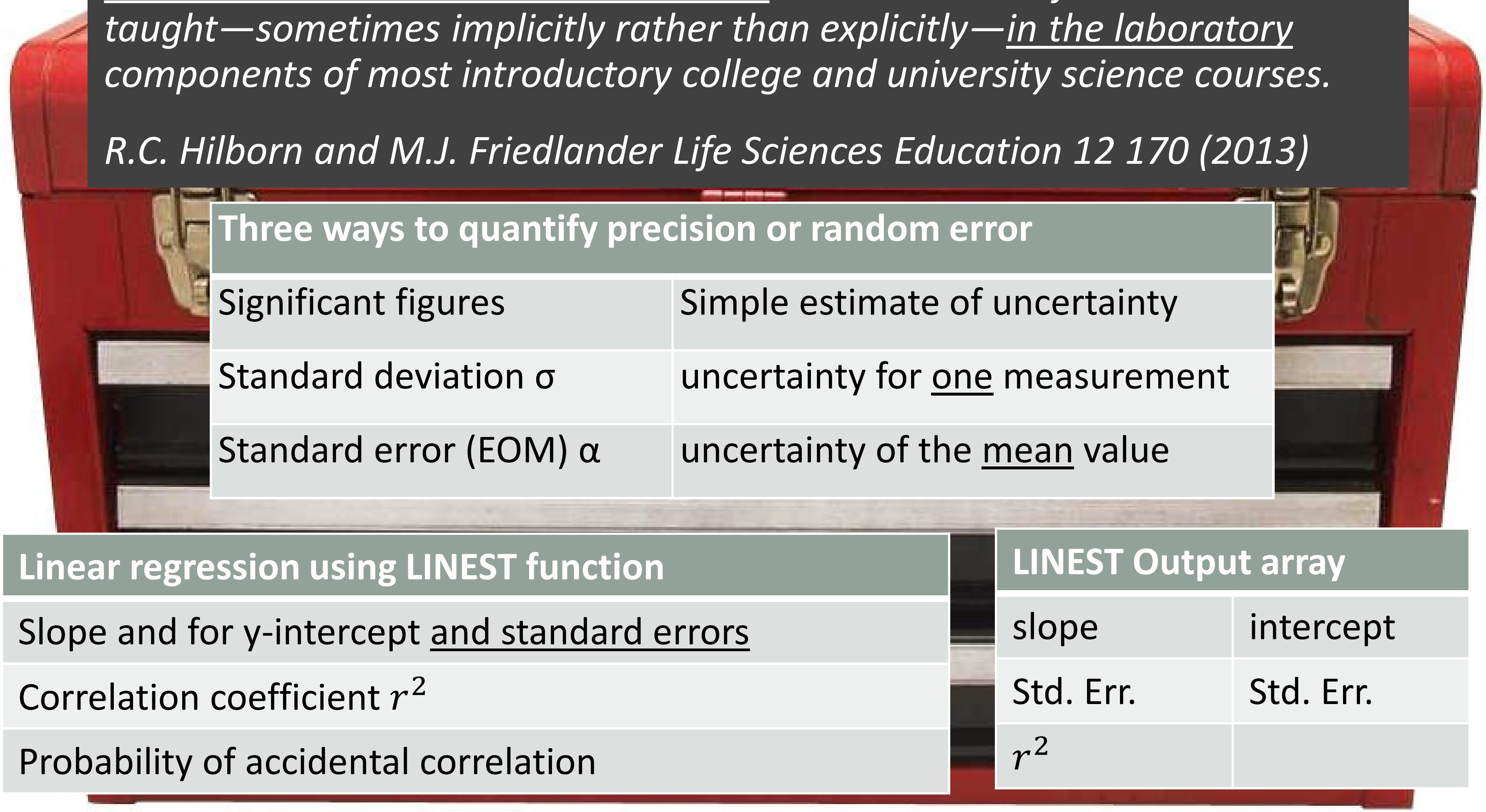
Standard deviation gives a CI for each measurement

	value
Estimated Std. Dev. σ	29
Calculated Std. Dev. σ	30

Confidence Interval	CI min (mg/dL)	CI max (mg/dL)	% within CI
68%	187	245	69%
95%	158	274	94%



Knowledge construction toolbox



Note that the quantitative skills focus on reasoning about data <u>using statistics and other mathematical tools</u>. These skills are just those that are taught—sometimes implicitly rather than explicitly—<u>in the laboratory</u> components of most introductory college and university science courses.

R.C. Hilborn and M.J. Friedlander Life Sciences Education 12 170 (2013)

Three ways to quantify precision or random error	
Significant figures	Simple estimate of uncertainty
Standard deviation σ	uncertainty for <u>one</u> measurement
Standard error (EOM) α	uncertainty of the <u>mean</u> value

Linear regression using LINEST function
Slope and for y-intercept <u>and standard errors</u>
Correlation coefficient r^2
Probability of accidental correlation

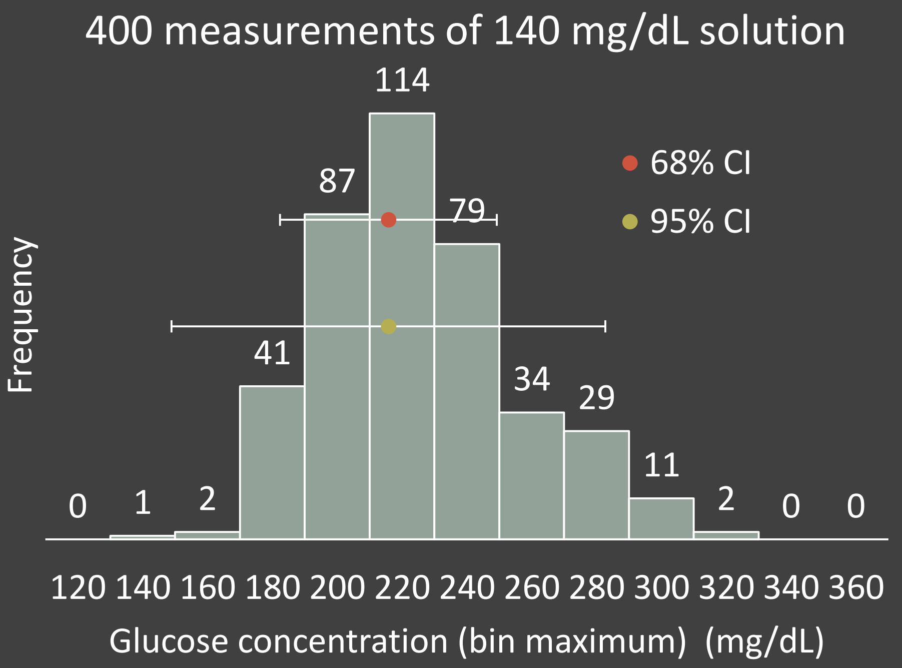
LINEST Output array	
slope	intercept
Std. Err.	Std. Err.
r^2	

Quantitative conclusions

- How precise is the device?
  - $216 \pm 60\, mg/dL$ (95% CL)
  - 28%
- What is the actual concentration?

$$\alpha = \frac{\sigma}{\sqrt{N}}$$

  - $216 \pm 2\, mg/dL$ (95% CL)
- Expected $140\ mg/dL$: random error?
  - Abs. Err.: $76\ mg/dL$
  - 50 standard errors
  - Faulty assumption!



Interval	Confidence level	"Chances"	measurements outside CI
$\bar{x} \pm \alpha$	68.27%	1 in 3	31%
$\bar{x} \pm 2\alpha$	95.45%	1 in 22	5%

Are students learning?

LET’S MEASURE!

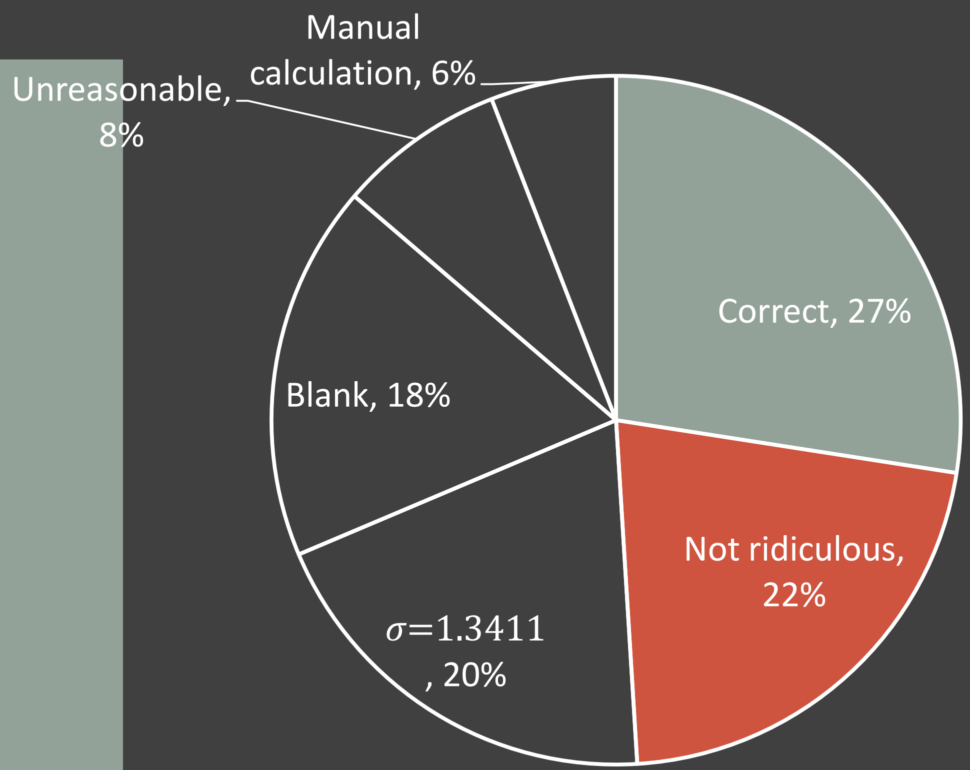
Are students learning?

Students meeting or exceeding expectations on final exam		
	Fall 2013	Fall 2014
Quantitative analysis	26%	62%
Interpretation of slope and intercept	43%	33%

Quant. analysis assessment 2

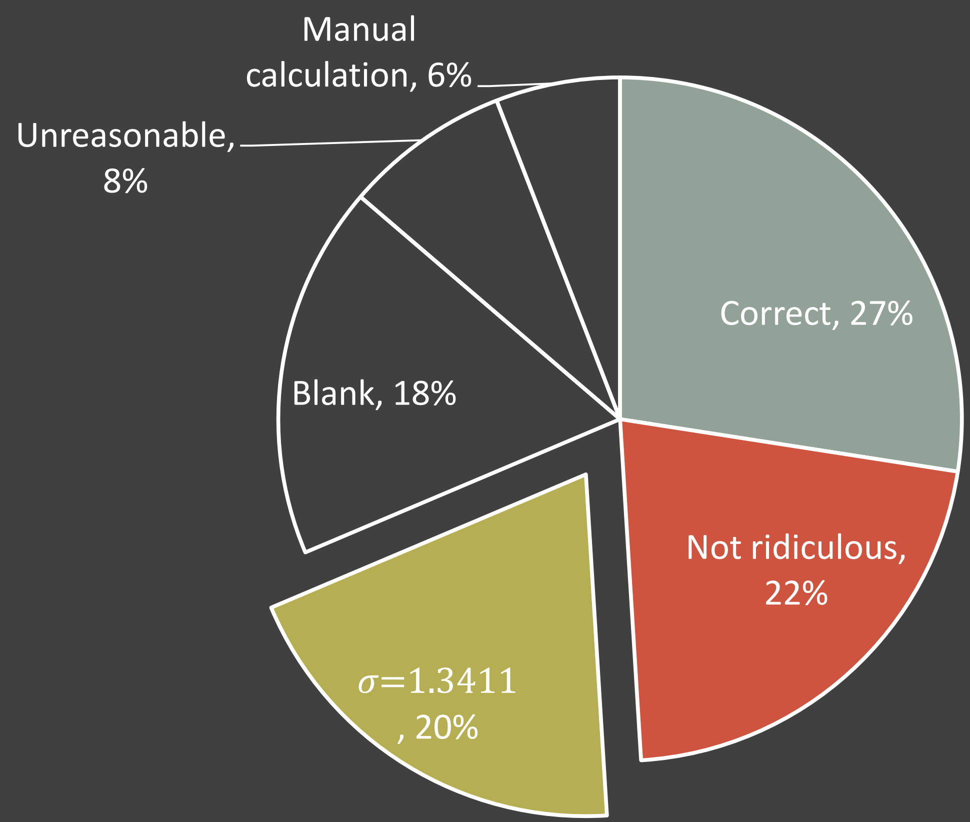
Single-concept "mini-test", (second test, N=51)

REDACTED: EXAM CONTENT



Quant. analysis assessment 2

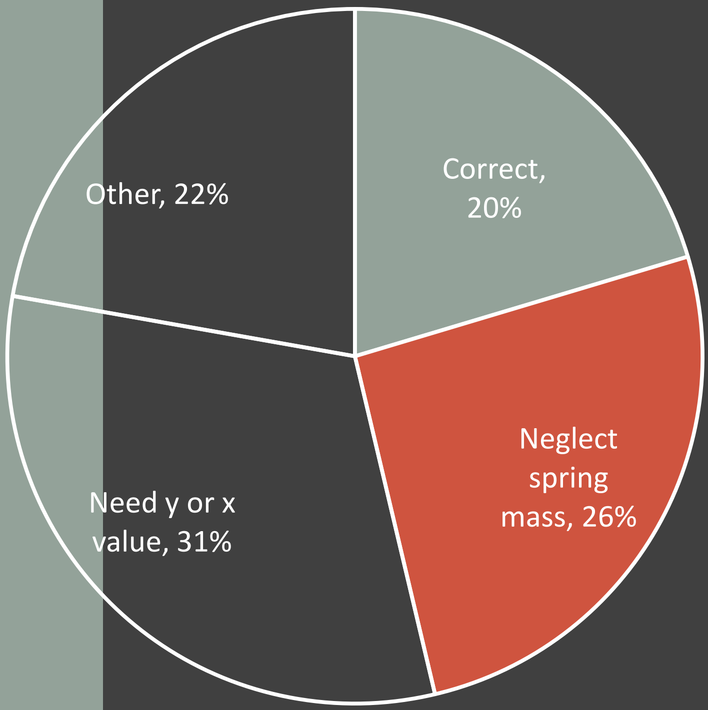
20% of students used $\sigma = average/\sqrt{N}$!



Interpret slope and intercept

REDACTED: EXAM CONTENT

Calculate mass from slope



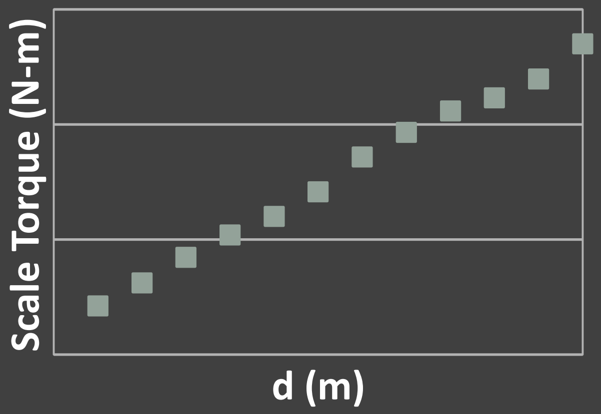
Need a better assessment tool

Lessons learned

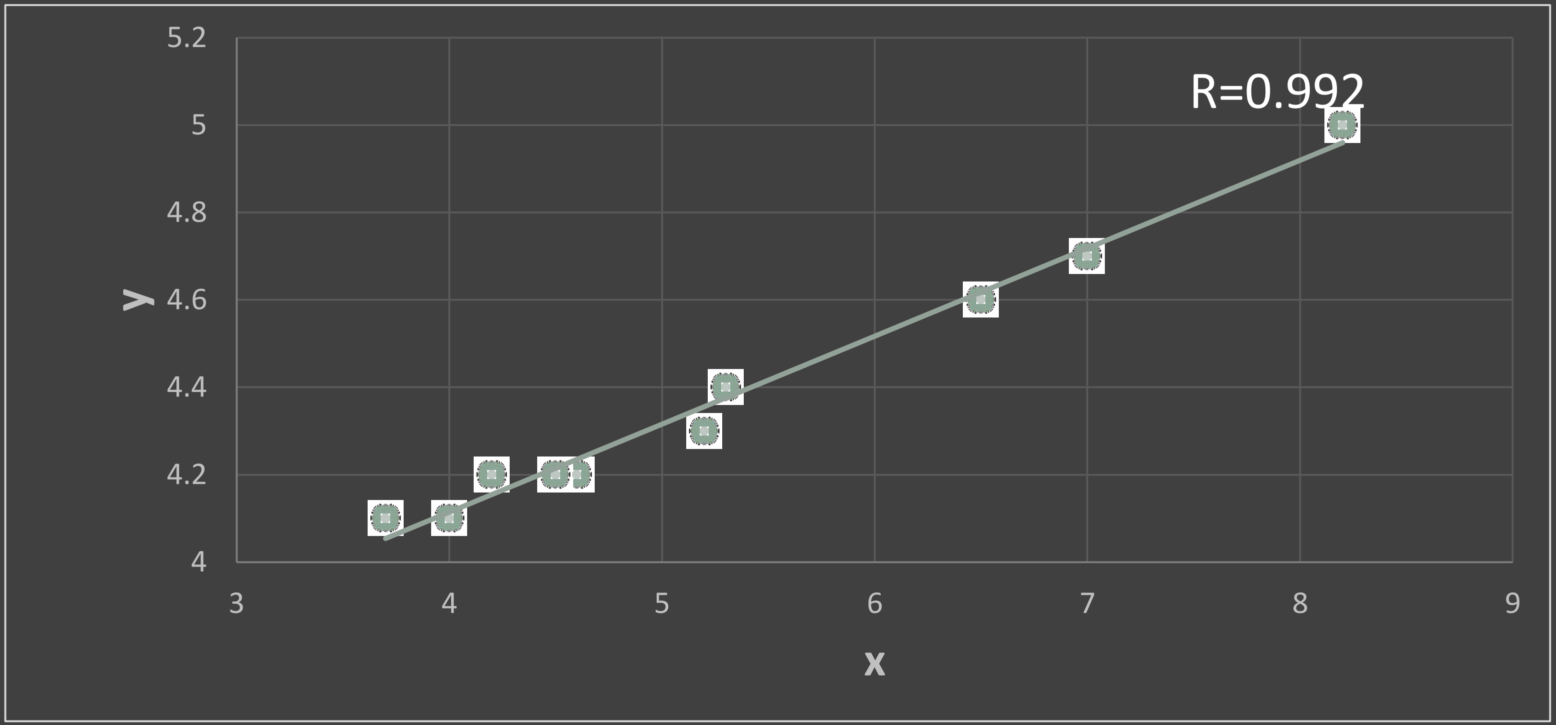
- No numbers on the axis
- Must have a theoretical y-intercept: $slope \neq \frac{y}{x}$

Challenges

- Separate from ability to choose the right model
- Conceptual error or algebra mistake?

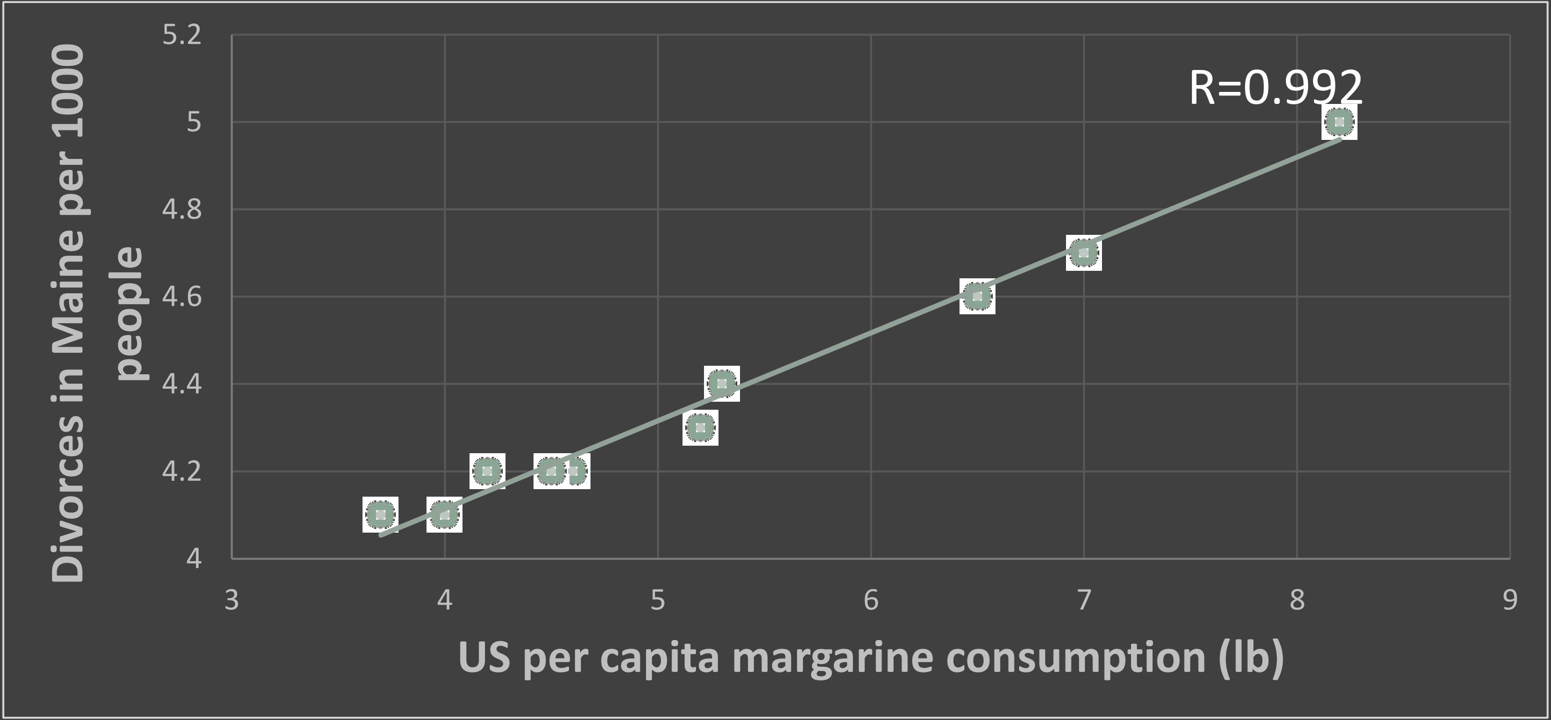


Prob. that y is correlated to x?



Prob. of accidental correlation

Tyler Vigen's Suprious Correlations



http://tylervigen.com/view_correlation?id=1703

I Didn’t Expect Applications to Life!

http://www.southern.edu/physicslabs

Who cares?

Backwards epistemology

- Should measurements make sense?
- *"We observed students, including the best students in the class, "going through the motions" in following the explicit protocols given in the lab manual…they did not expect to make sense of what was happening.* [1]"
- Is the purpose of empirical measurement to agree with authoritative knowledge?

Preparation for evidence-based practice

- *"Physicians should possess a deep understanding of the fundamental biomedical scientific principles needed to deal with the unexpected; they should not rely solely on algorithm-based practice.* [2]*"*
- Why should the future clinicians of America be able to rely on algorithm-based lab activities?

1. E.F. Redish, D. Hammer "Reinventing college physics for biologists: explicating an epistemological curriculum", American Journal of Physics **77** 629 (2009).

2. AAMC–Howard Hughes Medical Institute Joint Committee. Scientific Foundations for Future Physicians. Washington, DC: AAMC; 2009.