

Re-Numerating the Astronomy Classroom

restoring essential numerical skills and thinking
via astronomy education

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With support from the NSF Transforming Undergraduate Education in STEM Program

Agenda

- Introductions
- Quantitative Literacy (QL)
 - What?
 - Why important?
- The problem
- Why ASTRO 101?
- Ice breaker
- Interactive activities
- Our research and tools
 - QUarcs survey instrument
- Can Gen Ed astronomy courses improve QL skills and attitudes?

Introductions

- Don & Kate
 - IR astronomers and educators
 - University and community college undergraduates - primarily non-science
 - Pre-college students
 - Frustrated teachers
 - with the poor arithmetic abilities and attitudes of our students
 - Co-Is on an NSF TUES grant to study Quantitative Literacy
 - Kate developed the QuaRCS assessment tool
 - *“Can an ASTR 101 class improve students’ skills and attitudes towards QL?”*
- Audience introductions

What is “Quantitative Literacy”?

numeracy, quantitative reasoning, ...

NOT math !

“a person’s (ability) to make sense of the numbers that run their lives”

(Hofstadter)

... the ability to reason with numbers, graphs, statistics, etc. in order to be an effective participant in modern society

“Quantitative literacy involves sophisticated reasoning with elementary mathematics more than elementary reasoning with sophisticated mathematics.”

(Steen, 2004 – from WISDOME book)

The Problem

U.S. students have not mastered 5-7th grade arithmetic.

limits depth in science courses
may foster pseudoscience

Poor Skills

fractions – decimals – ratios - percentages – powers of ten

“10% off price” is a challenge.

“inverse-square” seems too advanced.

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
$4.3 \times 10^0 =$	4.3000000

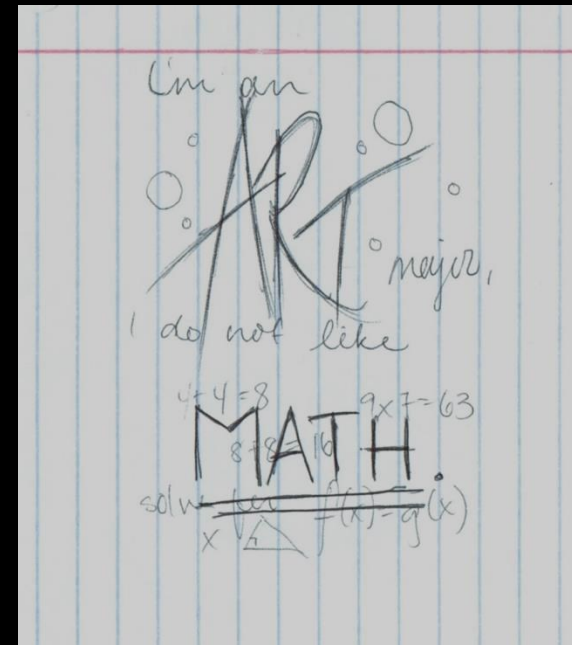
Perhaps Worse:

poor attitudes and experiences
don't use numbers in language

"The only purpose of math is to pass a test in math class."
(Honor's student – university)

"I'm no good at math and that's why I'm going to be an elementary school teacher."
(student – university)

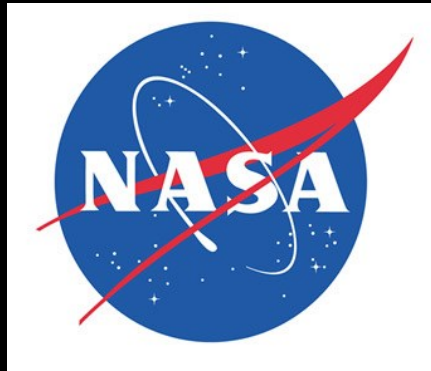
"I have never seen math and science used together."
(Honor's student – middle school)



Reality is mathematical in nature ← no wonder I'm so bad at life.

Citizenship and QL

voters, consumers, teachers



NASA's Budget (2011)
\$18.724 billion



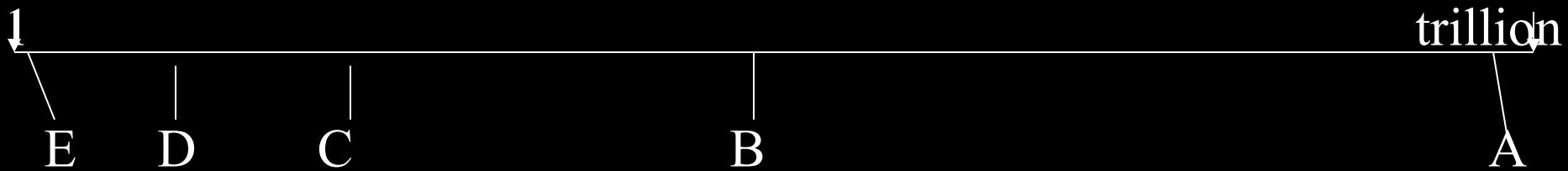
U.S. Budget (2011)
\$3.630 trillion

"There are 10^{11} stars in the galaxy. That used to be a huge number. But it's only a hundred billion. It's less than the national deficit! We used to call them astronomical numbers. Now we should call them economical numbers."

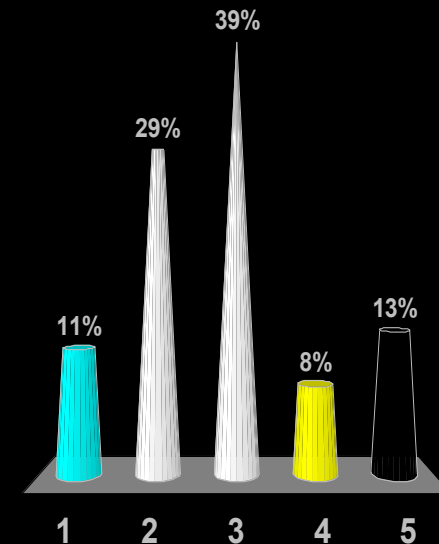
Richard Feynman
U.S. educator & physicist (1918 - 1988)

A sense of “scale” is important in most topics.

Where is one billion on this scale?

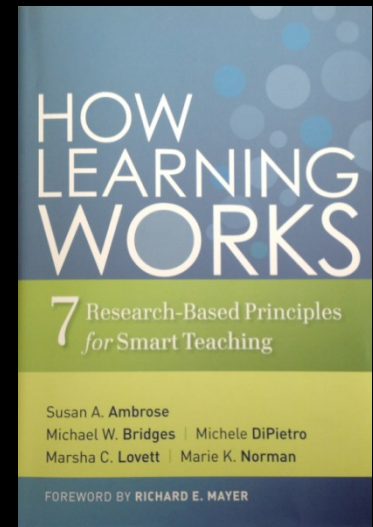
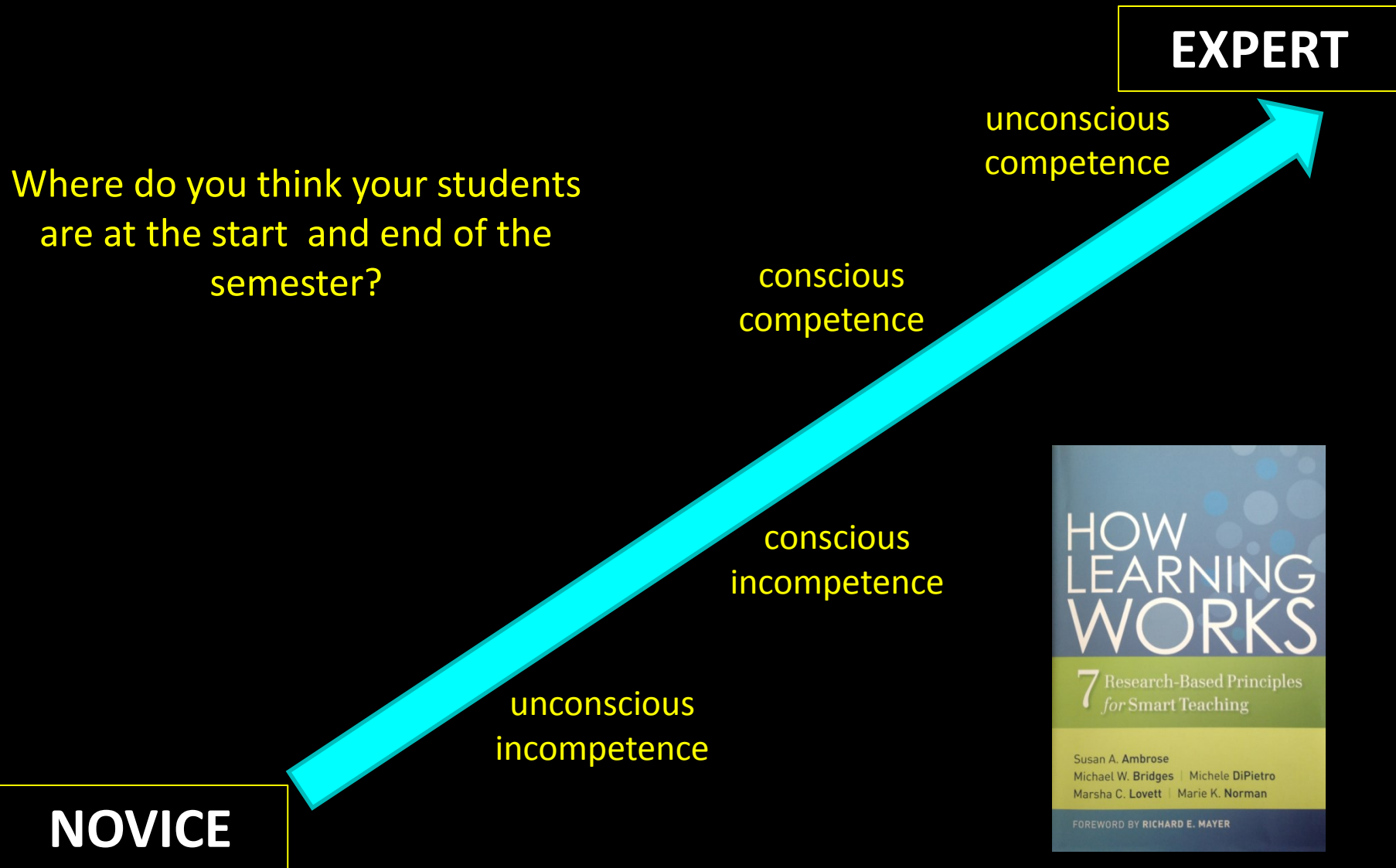


1. A
2. B
3. C
4. D
5. E



responses from a typical Gen Ed class of college freshmen at start of semester

Where do you want your students to be?



Can ASTRO 101 Improve This Situation?

the subject of our research

- >10% of college students take “Astronomy 101” in college.
 - 5-10% of them are future educators (~30,000 !)
 - often the “terminal” science course
- Attracts mathematically disinclined students
- Inherently interesting, numerically rich subject → the “cool” factor
 - and can make numbers come alive

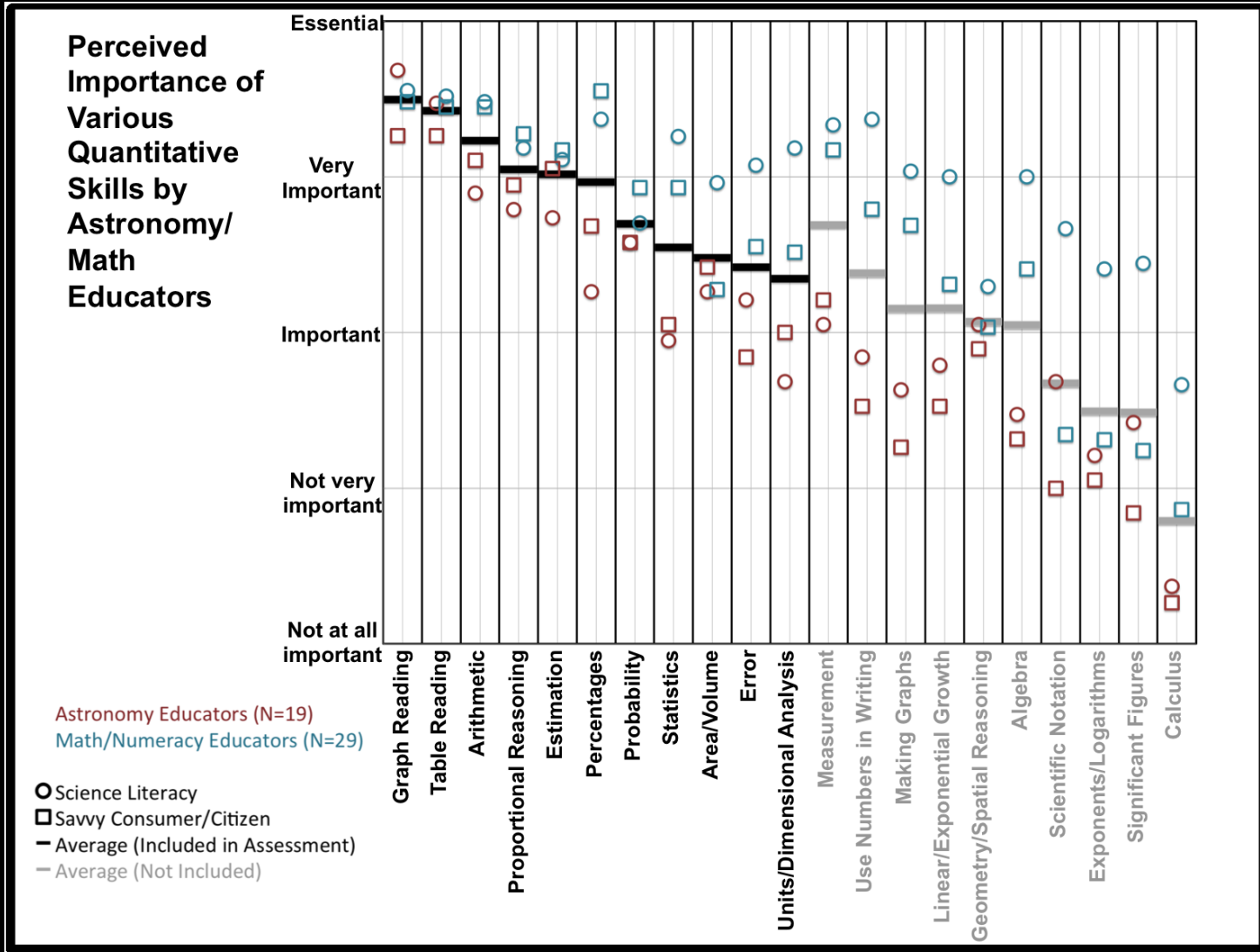
Icebreaker Activity

Which quantitative skills are important in STEM?

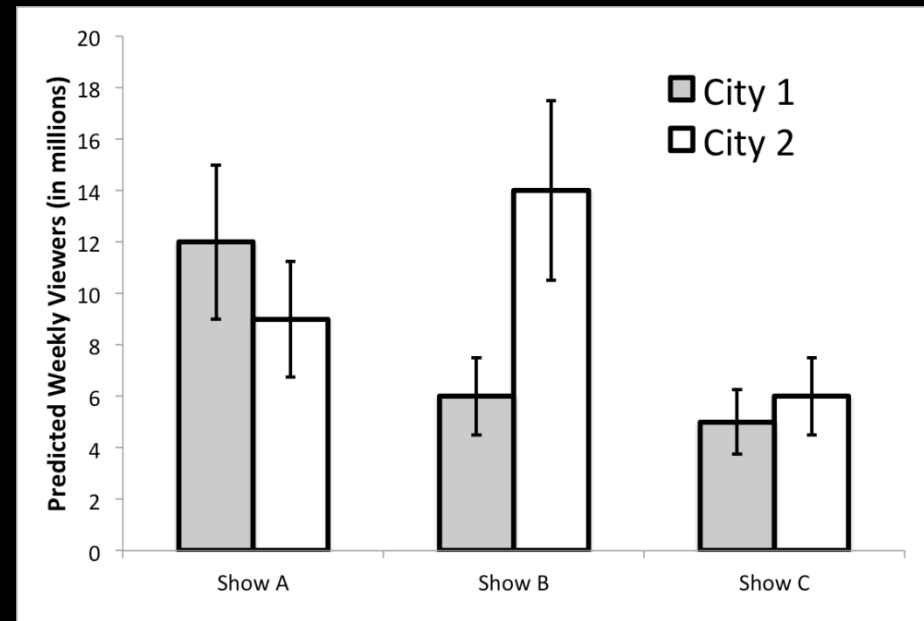
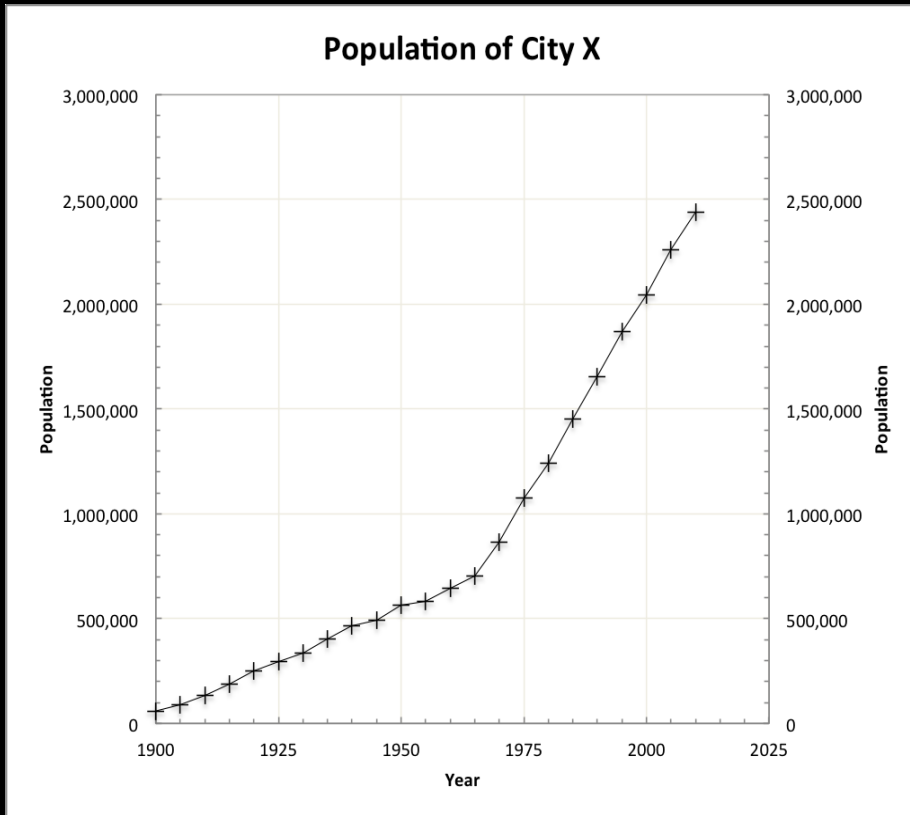
- Algebra
- Area and Volume
- Calculus
- Dimensional Analysis and Unit Conversions
- Error, Precision, Accuracy
- Estimation
- Exponents and Logarithms
- Geometry and Spatial Reasoning
- Interpret Graphs
- Interpret Tables
- Linear and Exponential Growth
- Measurement
- Percent and Percent Change
- Plotting/Making Graphs
- Probability, Odds, Risk
- Proportional Reasoning
- Scientific Notation
- Significant Figures
- Simple Operations (+/-/x/÷)
- Statistics
- Using Numbers in Written Work

In Life??

STEM Educator Survey



Sample Questions

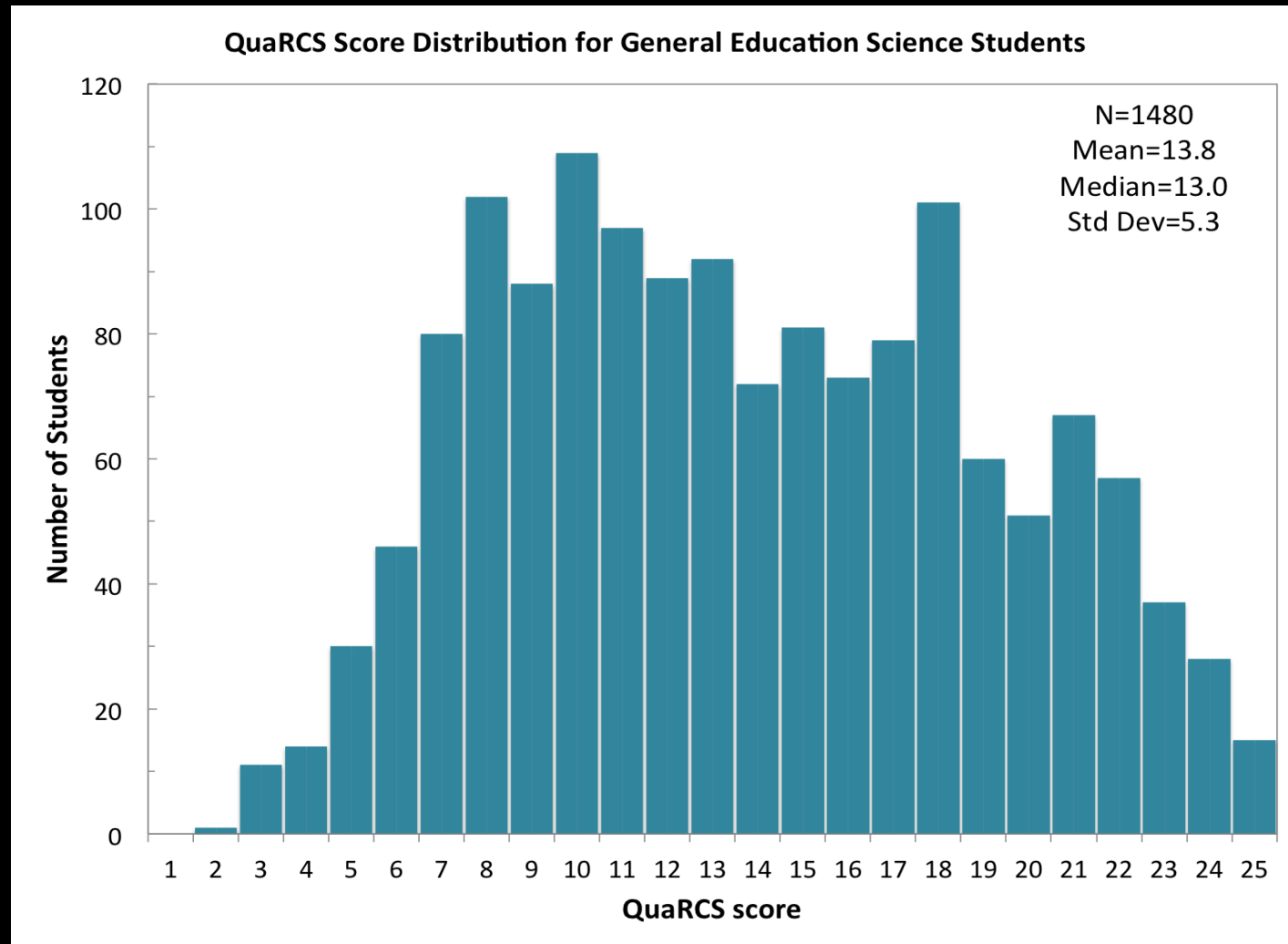


Your cable bill is \$36 per month from January 1 through September 30 and then doubles to \$72 per month starting October 1. What is your average monthly bill over the course of the entire calendar year (January-December)?

Number of Injuries by Ability Level for Skiers at Resort Y in the Years 2000-2010

Level of Expertise	Total Visitors	Number of Minor Injuries	Number of Severe Injuries	Number of Deaths
Novice	12,152	384	122	1
Intermediate	9,498	96	65	0
Expert	802	11	16	5
Totals	22,452	491	203	6

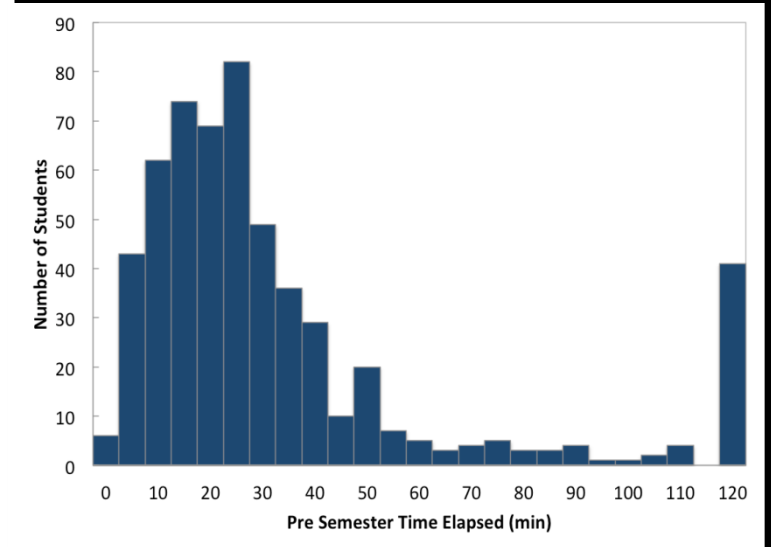
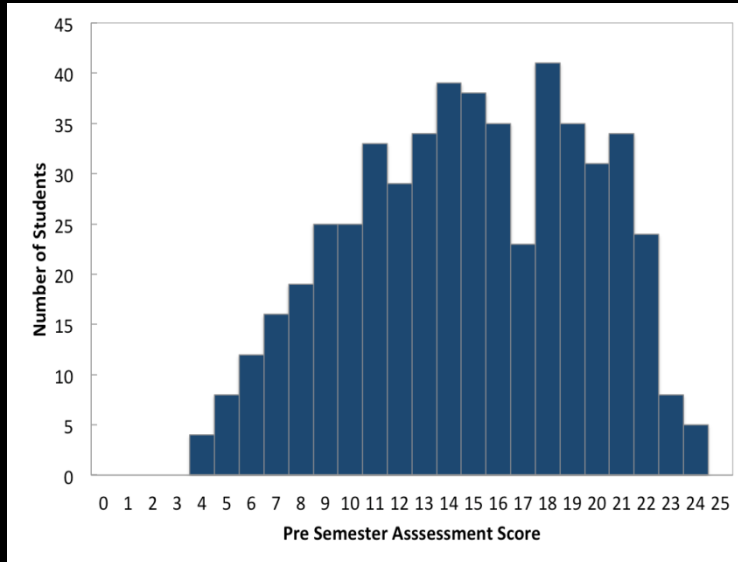
Score Distribution



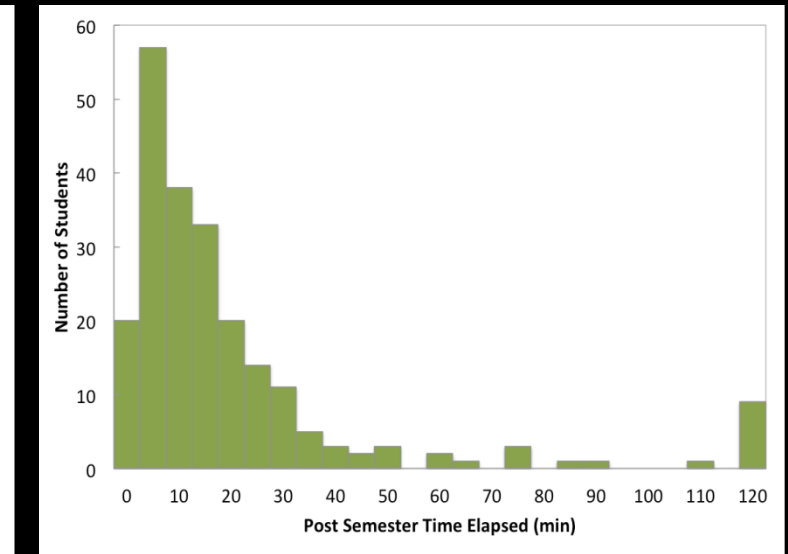
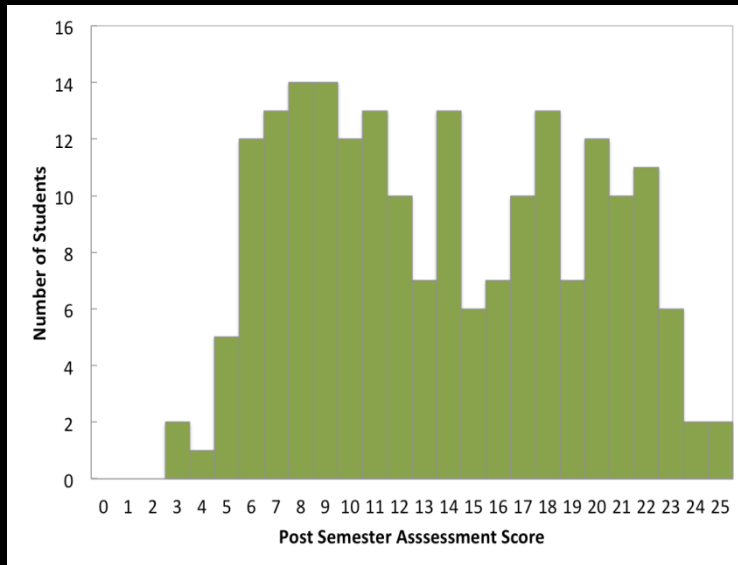
SCORE

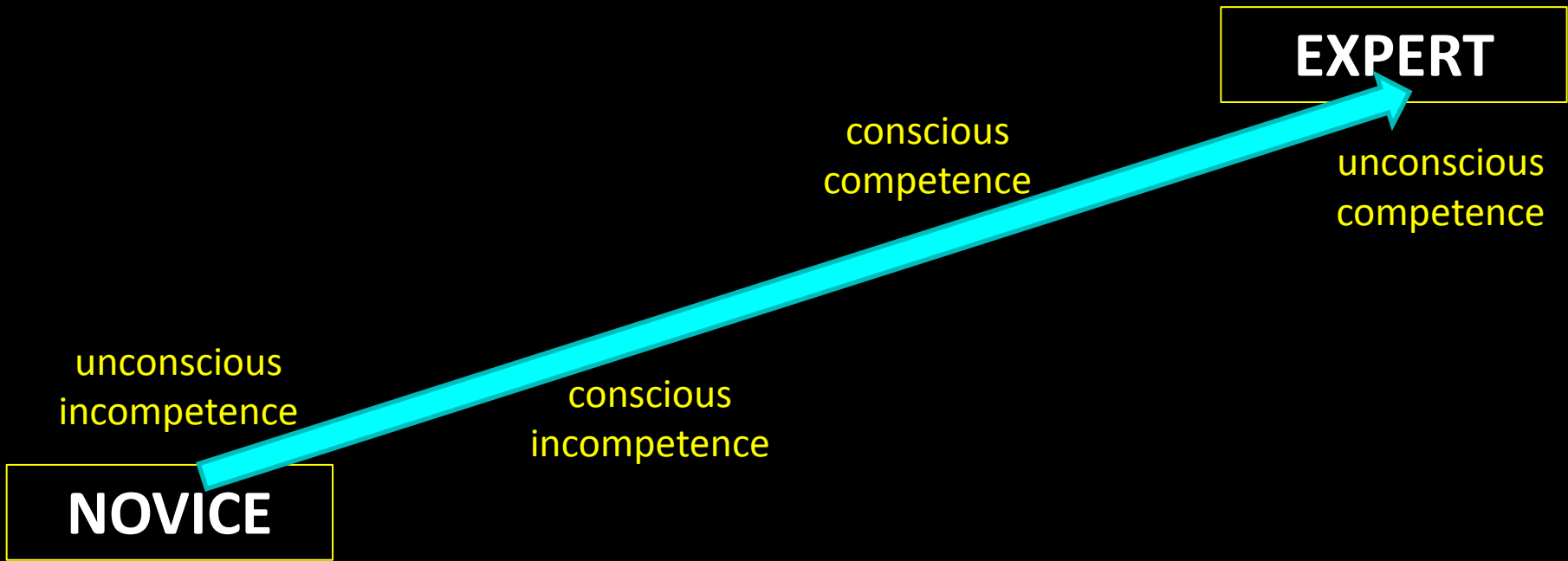
Time

PRE

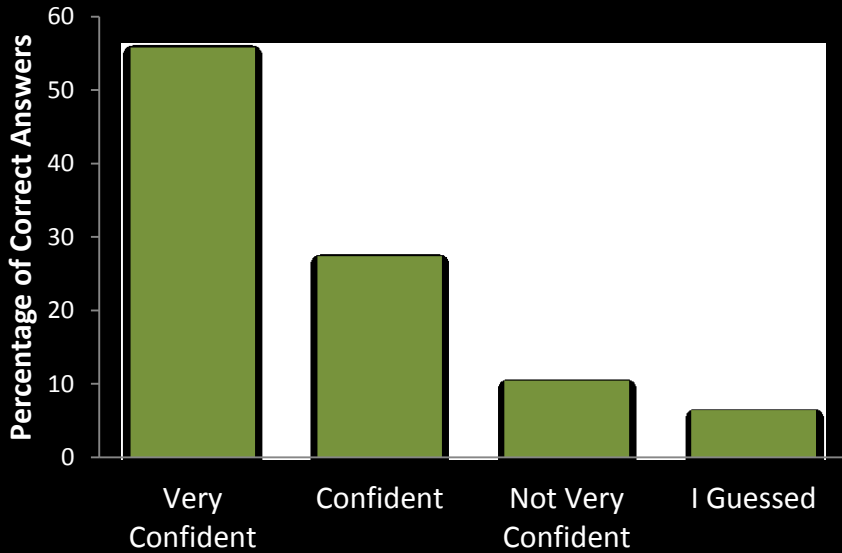


POST

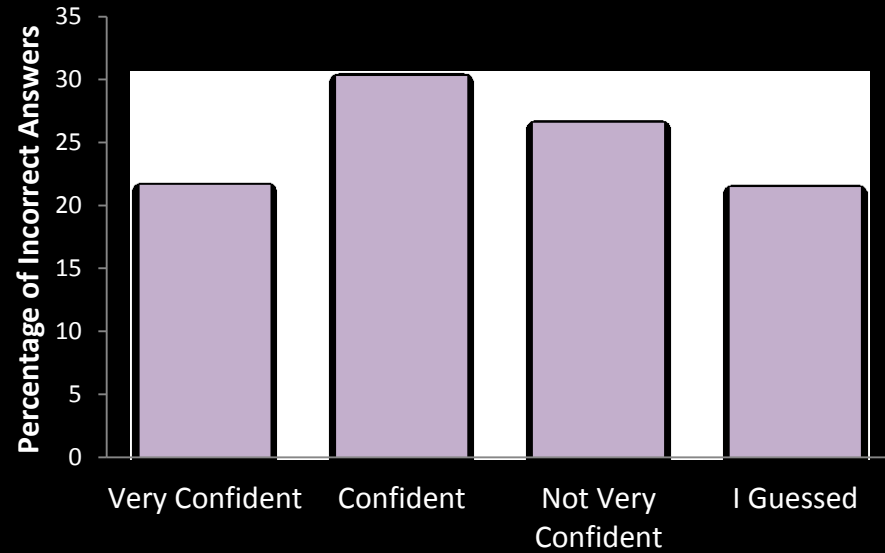




Correct Answer Confidence



Incorrect Answer Confidence

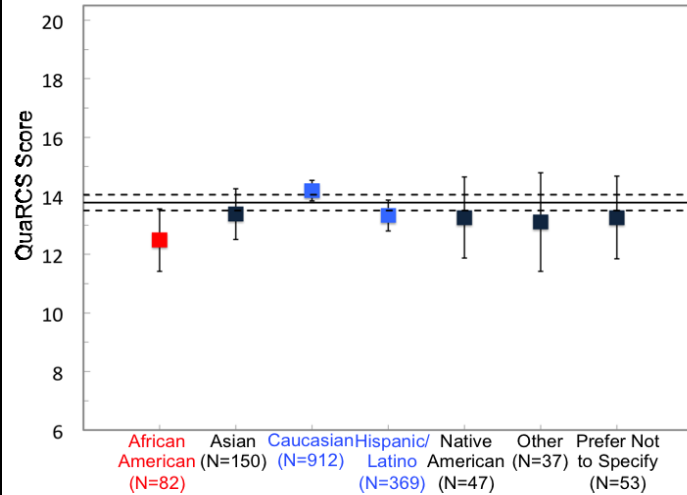


Attitude Questions

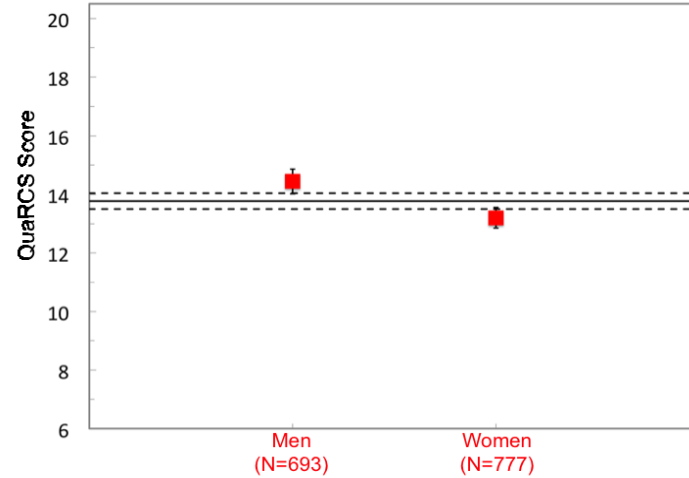
- Basic demographics: race, gender, age, disability status
- Academic demographics: class, major, most recent math course, intended math/science coursework, reason for choosing course/major
- Attitudes/perceptions about numbers, graphs and mathematics

Basic Demographics

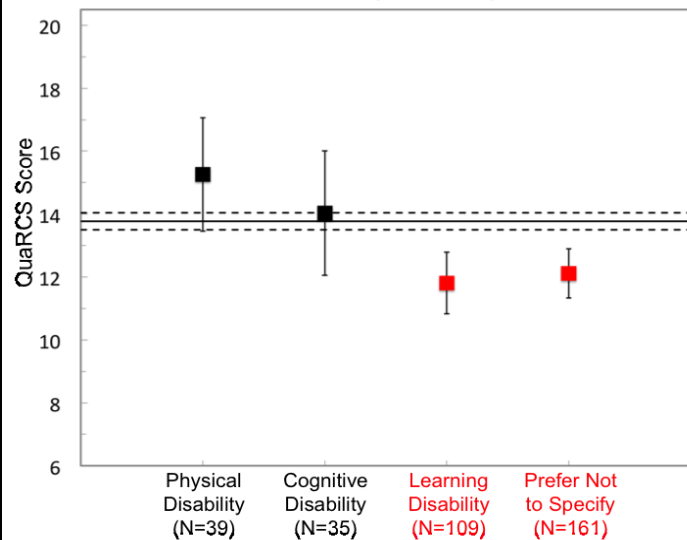
Assessment Score By Race



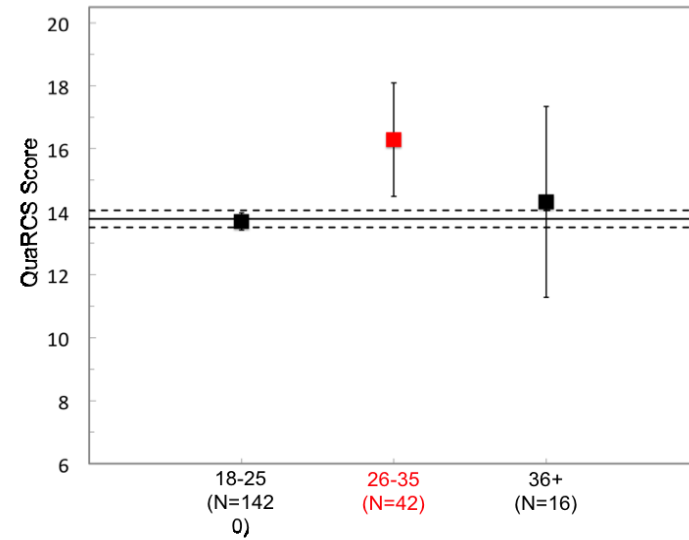
Assessment Score By Gender



Assessment Score By Disability Status

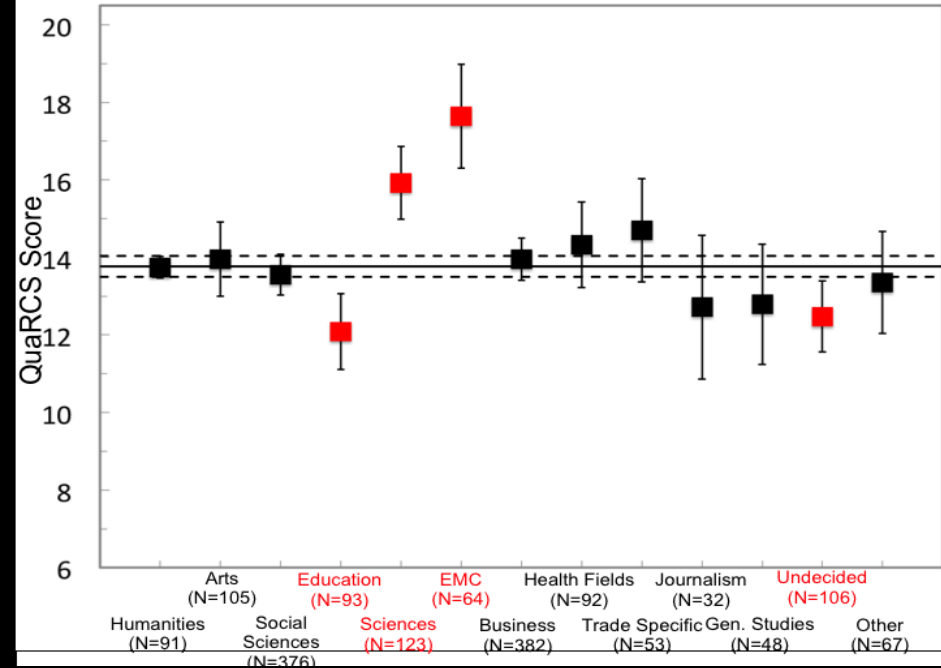


Assessment Score By Age

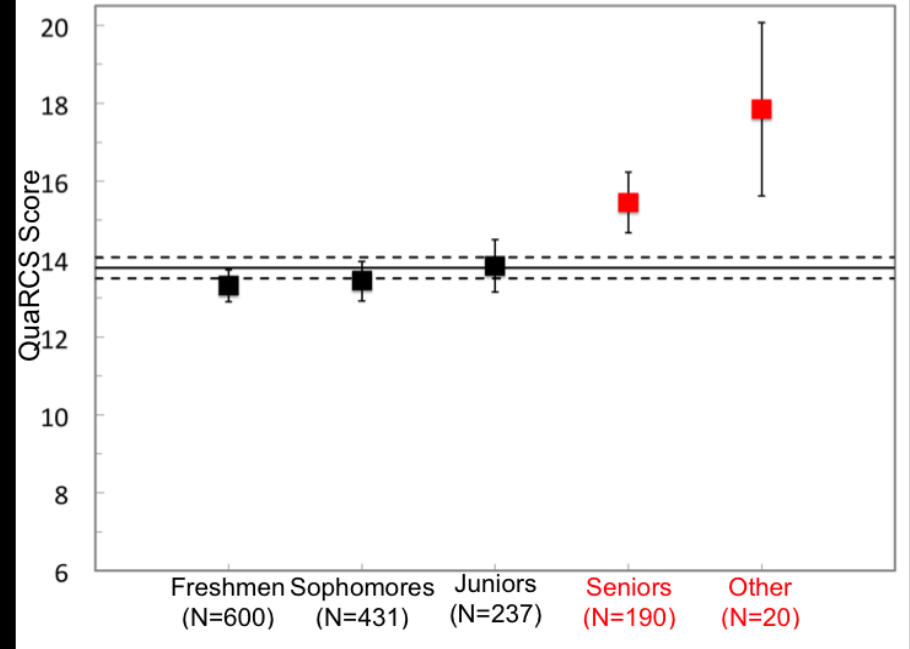


Academic Demographics

Assessment Score By Major

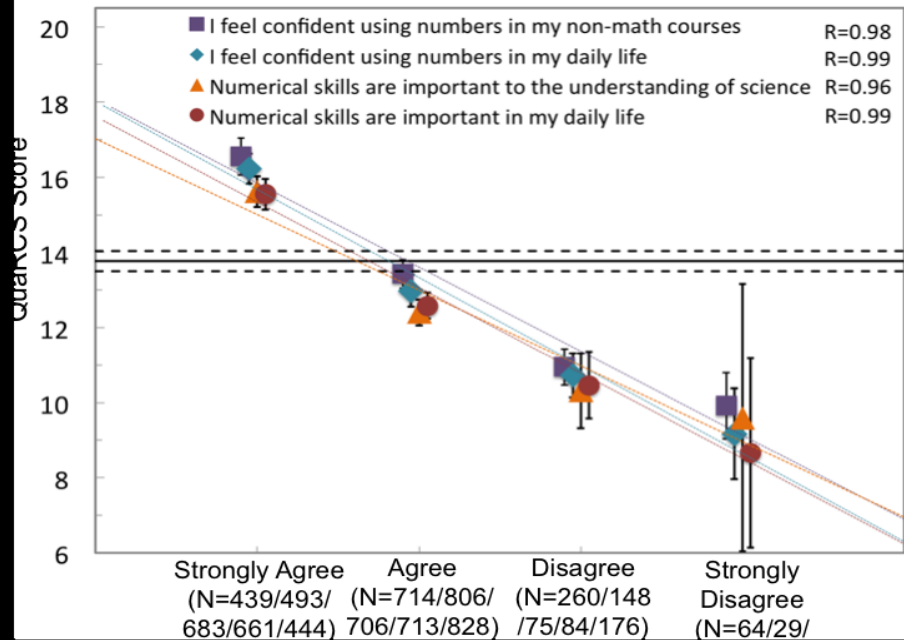


Assesment Score By Class

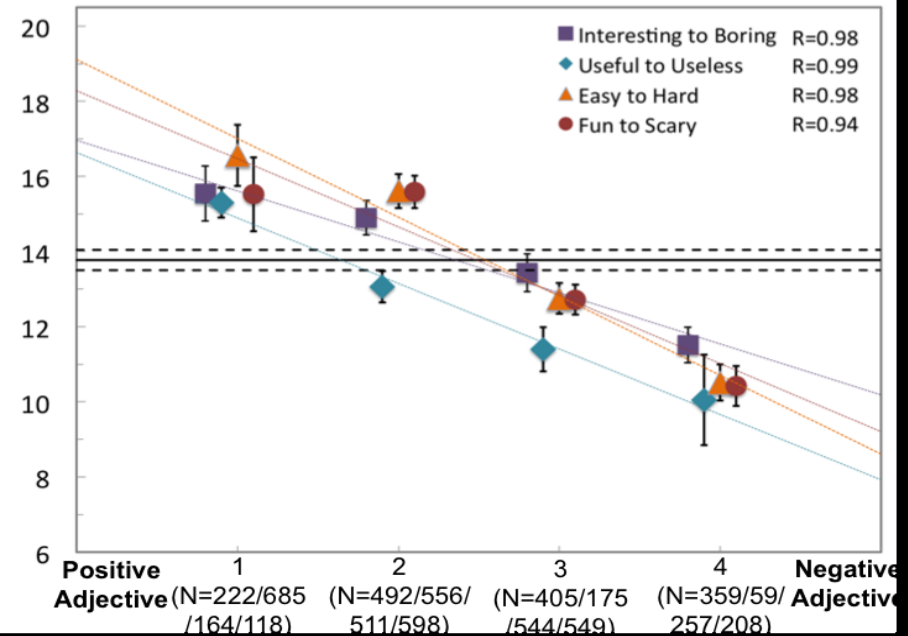


Attitudinal Correlations

Assessment Score By Level of Agreement with Statements



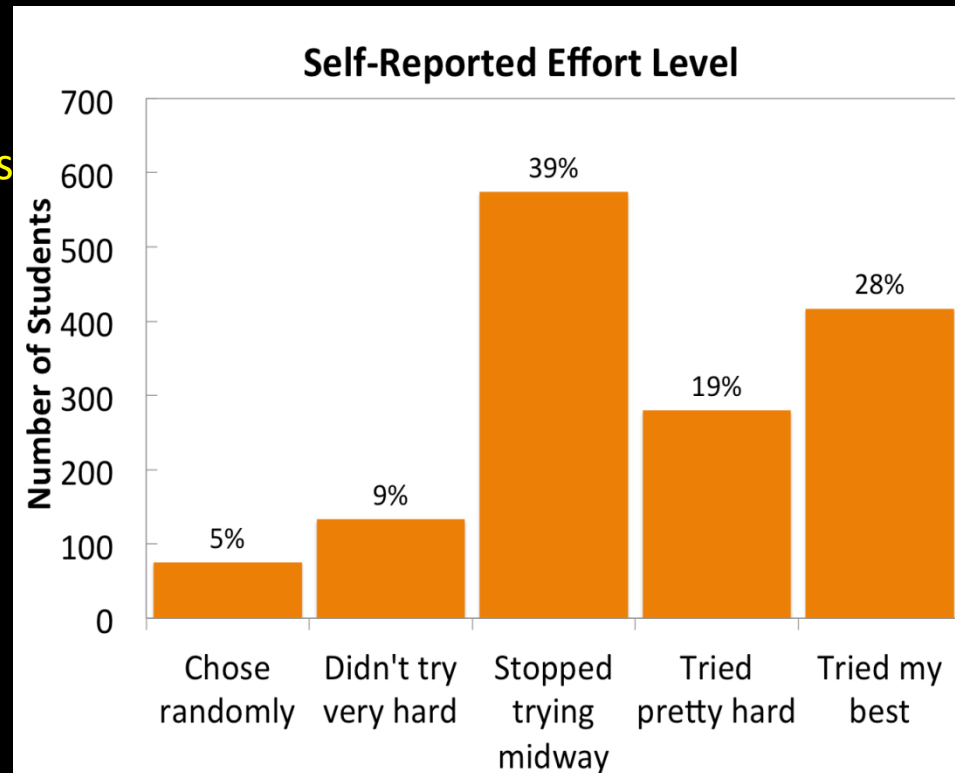
Assessment Score By Opinions About Doing Mathematics

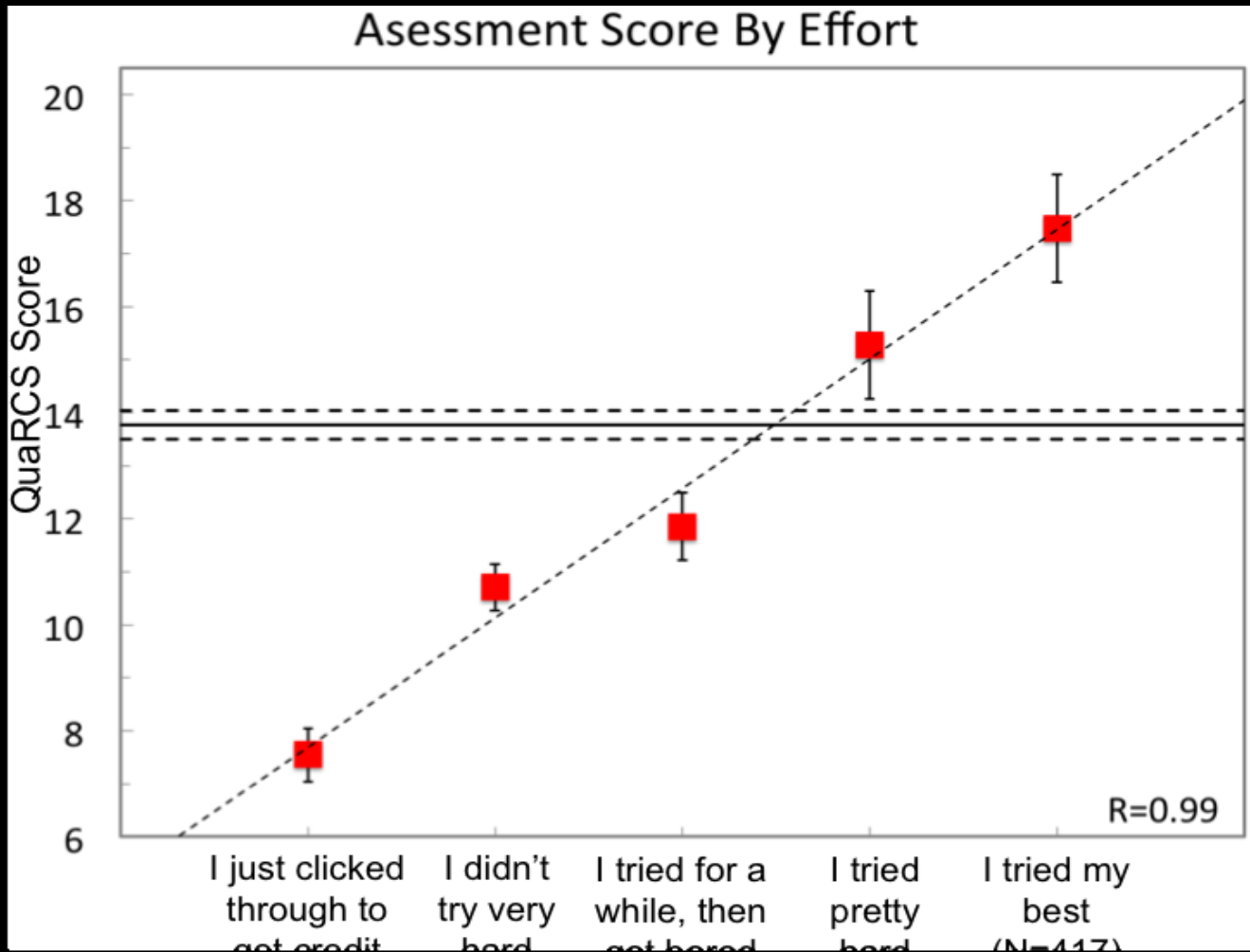


Self-Reported Effort

Knowing that this survey is being used for research to try to improve courses like yours and that your answer to this question will not be shared with your instructor, please honestly describe the amount of effort that you put into this survey.

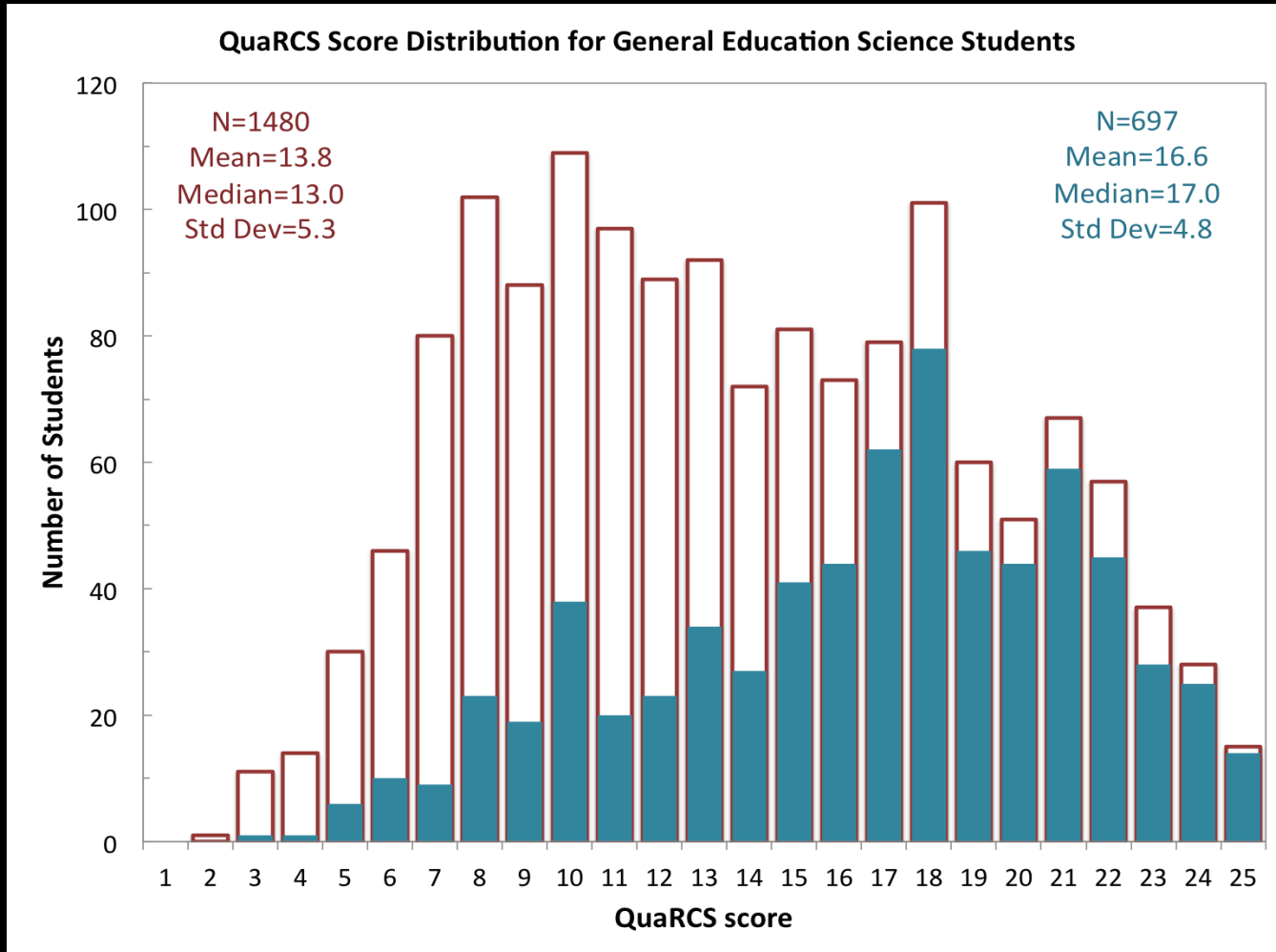
- a) I just clicked through and chose randomly to get the participation credit
- b) I didn't try very hard
- c) I tried for a while and then got bored
- d) I tried pretty hard
- e) I tried my best on most of the questions



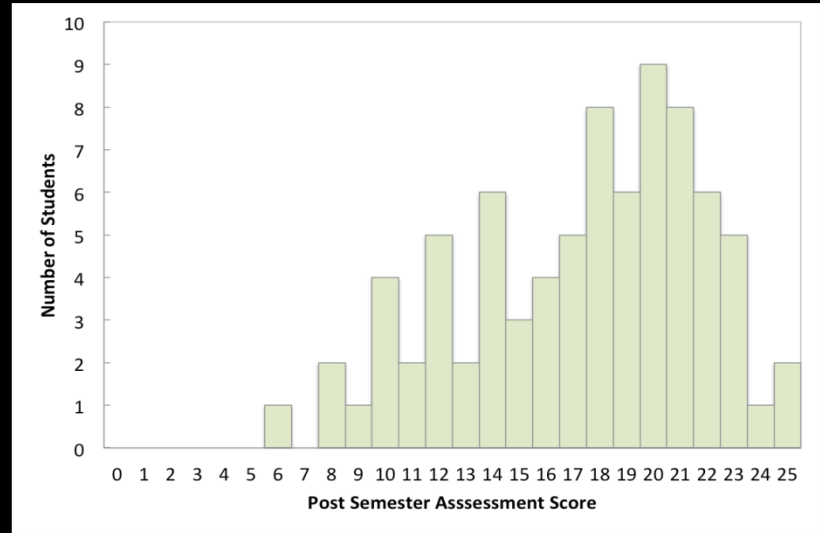
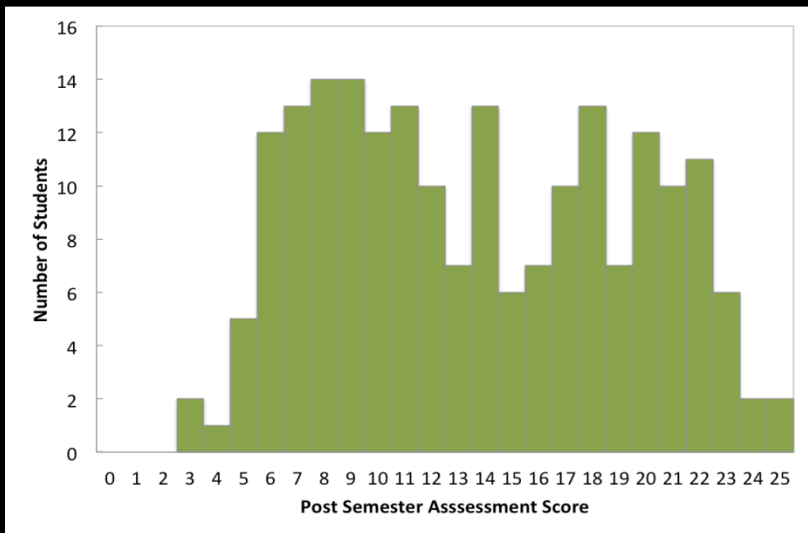
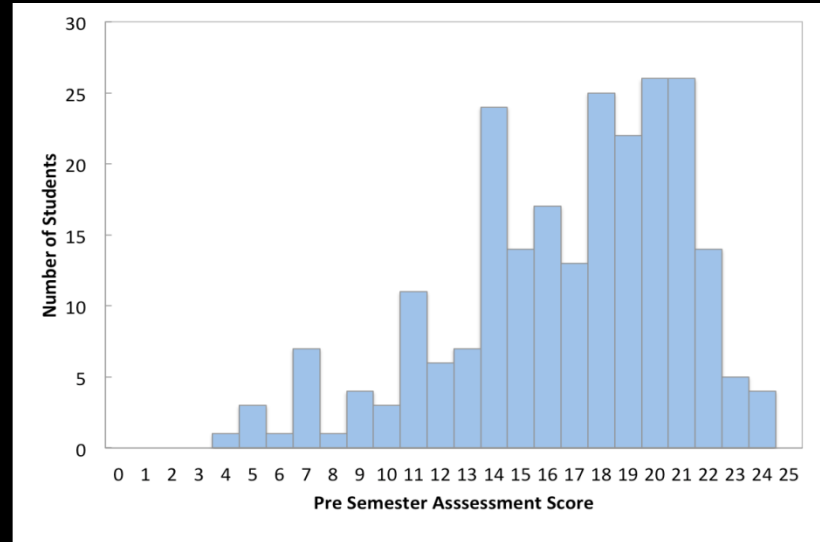
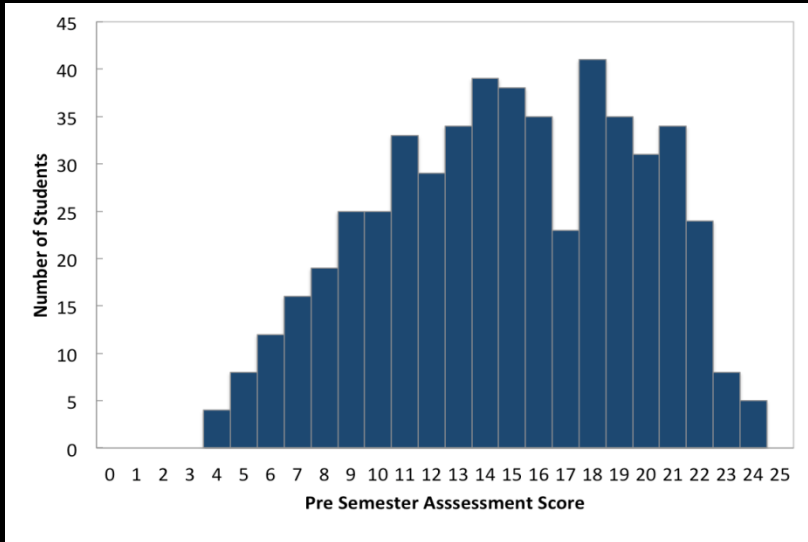


Explains 29% of variation in QuaRCS score

Scores by Effort



Pre/Post Scores



Class 1 (N=145,122)

Adjective	Pre to Post Change
Interesting	5.66%
Useful	2.72%
Useless	-1.09%
Boring	-4.19%
Hard	-3.11%

Classes 2&3 (N=42,28)

Adjective	Pre to Post Change
Interesting	3.50%
Useful	7.73%
Useless	-3.11%
Boring	-6.11%
Hard	-2.00%

Classes 4,5 & 6 (N=72, 30)

Adjective	Pre to Post Change
Interesting	-9.94%
Useful	-2.43%
Useless	1.07%
Boring	10.38%
Hard	0.93%

Class 7 (N=416,336)

Adjective	Pre to Post Change
Interesting	3.09%
Useful	0.78%
Useless	-1.21%
Boring	-1.47%
Hard	-1.19%

How Do We Achieve Improved Attitudes?

- Frequent quantitative brainteasers
- Numerically-rich ungraded activities (TPS questions, lecture tutorial supplements) leading up to homework questions and labs
- Labs and activities that tie scientific and quantitative reasoning skills to real life problems
- Require students to put their answers in context – no boxing the answer and moving on!
- Lead with phenomenological explanations before showing equations
- “TBD” grades for remediation

What we do NOT do:

- A “Math Unit” or “Math Review Day”
- Ask students to calculate or drill numerical skills (e.g. scientific notation) out of context
- Heavy Algebra, Plug-and-chug, procedural math

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 1.5×10^8 km. The diameter of the Earth is 1.3×10^4 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.

Choose one of the following 5 common
ASTRO 101 topics (or choose your own):
Hubble's Law, Lookback time, Planetary
resurfacing, Spectroscopy, Cosmic expansion

In groups of 2-3, write a homework question
for one of these topics that fulfills the
following criteria:

- (a) requires 1 or more of the quantitative
skills from the list
- (b) connects the concept to something in
students' daily lives
- (c) requires students to put their answer into
context and explain their reasoning

Area and Volume
Dimensional Analysis/Unit
Conversions
Error
Estimation
Interpret Graphs
Interpret Tables
Percentages
Proportional Reasoning
Simple Operations (+/-/x/÷)
Statistics and Probability

Don: Immersing students in a QL culture

- Fun problems
- Interactions in/out of classroom
- Interpretative situations
- Numbers in language:
 - personal essays and summaries
 - discussions

Can you pose an interesting question from this info?
Can you use these concepts in class?

Sally: \$100,000 salary
\$5,000 raise

Bob: \$10,000 salary
\$1,000 raise

Who received the larger raise?

Sally: \$5,000 raise

Bob: \$1,000 raise

Sally: \$100,000 salary

Bob: \$10,000 salary

If Bob and Sally work for the same company, who would feel happier about the raise?



Earth vs. a Basketball

Which object is smoother??

- Diameters:
 - Earth = 7926 miles
 - basketball = 25 cm
- Surface roughness:
 - Mt. Everest to Marina Trench = 12.3 miles
 - lumps on basketball = 1 mm
- *Justify your answer in **one or two** sentences by discussing the numbers.*



Star Trails

a long exposure picture looking north
towards Polaris

Develop a

Think > Pair > Share question

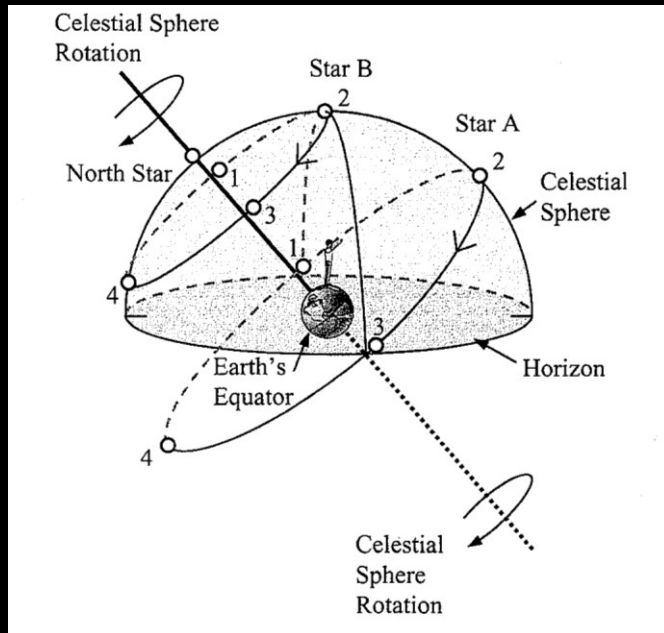
Estimate the approximate exposure time.

What fraction of a day?

1. 24 hours - 100%
2. 4 hours - 16%
3. 6 hours - 25%
4. 12 hours - 50%



“Lecture Tutorials” and QL Discussion



Would you ...

1. leave as-is?
2. add QL into the statement(s)?
3. use QL in a more advanced follow-up?

Student 1: *Locations B1 and B3 are on my horizon because they are rising and setting just like A1 and A3.*

Student 2: *Figure 1 shows that Star B is as low as it will get when it is just above the northern horizon at B4. So Star B never goes below the horizon.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

“Lecture Tutorials” and QL Discussion

Would you ...

1. leave as-is?
2. add QL into the statement(s)?
3. use QL in a more advanced follow-up?

Student 1: *If the distance to the star is more than 1 parsec, then the parallax angle must be more than 1 arcsecond. So a star that is many parsecs away will have a large parallax angle.*

Student 2: *If we drew a diagram for a star that was much more than 1 parsec away from us, the triangle in the diagram would be pointier than the one we just drew in Part II. That should make the parallax angle smaller for a star farther away.*

“Lecture Tutorials” and QL Discussion

Would you ...

1. leave as-is?
2. add QL into the statement(s)?
3. use QL in a more advanced follow-up?

Student 1: *I think the majority of the mass in the solar system must include both the Sun and the planets. As you get farther away from the Sun, the interior mass gets bigger and bigger because you include more planets.*

Student 2: *I disagree. The majority of the mass in the solar system is from just the Sun by itself. Sure the mass gets a little bigger as you include more planets, but the additional mass from planets is really small.*

Conclusions

You fill in the blank!

1.

2.

3.

4.

5.

Thank You!

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Funding



Collaborators

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“Re-Numerate”
Newsletter



QuaRCS
development and
validation article
published in
Numeracy

