

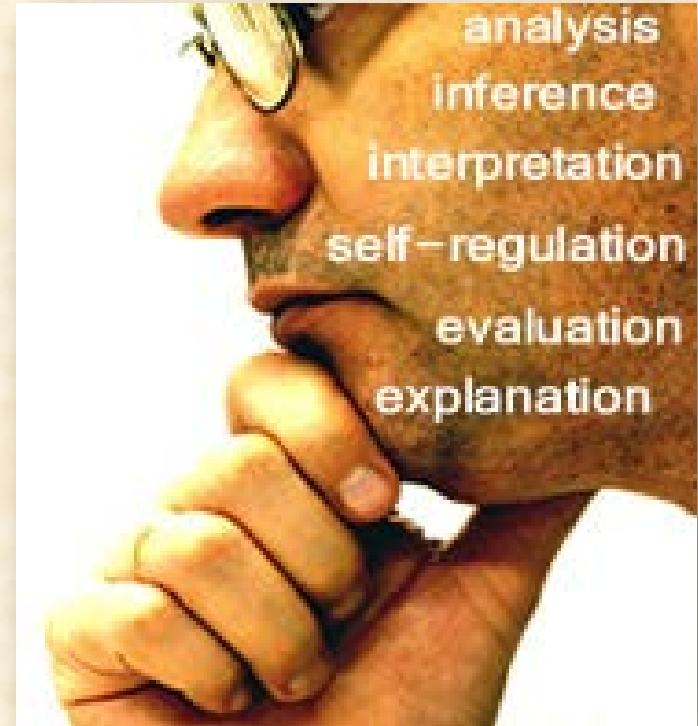
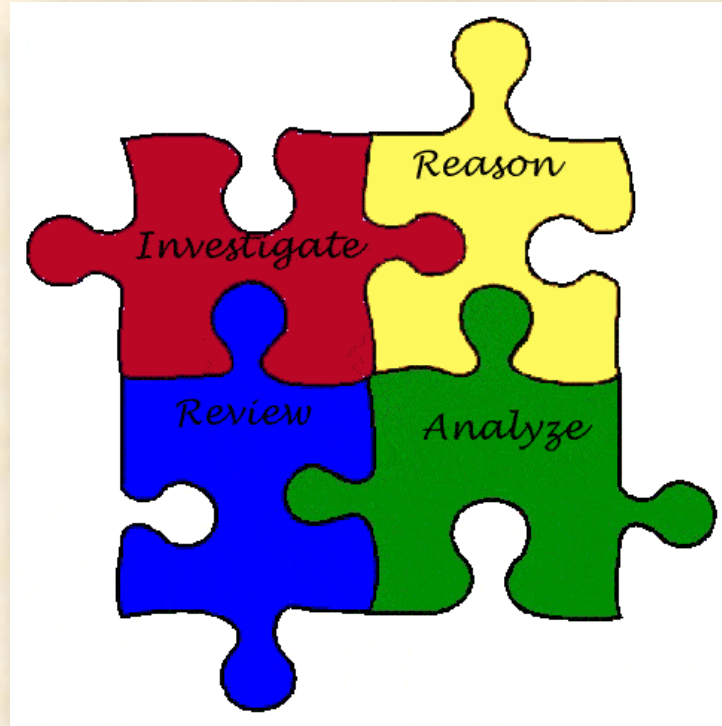
Interdisciplinary Approaches in Undergraduate Science Education: *Redesigning Intro Science Courses to Promote Critical Thinking*



**Matthew Rowe,
Marcus Gillespie,
Lori Rose, &
Li-Jen Shannon**

Sam Houston State University

According to nation-wide surveys of faculty:

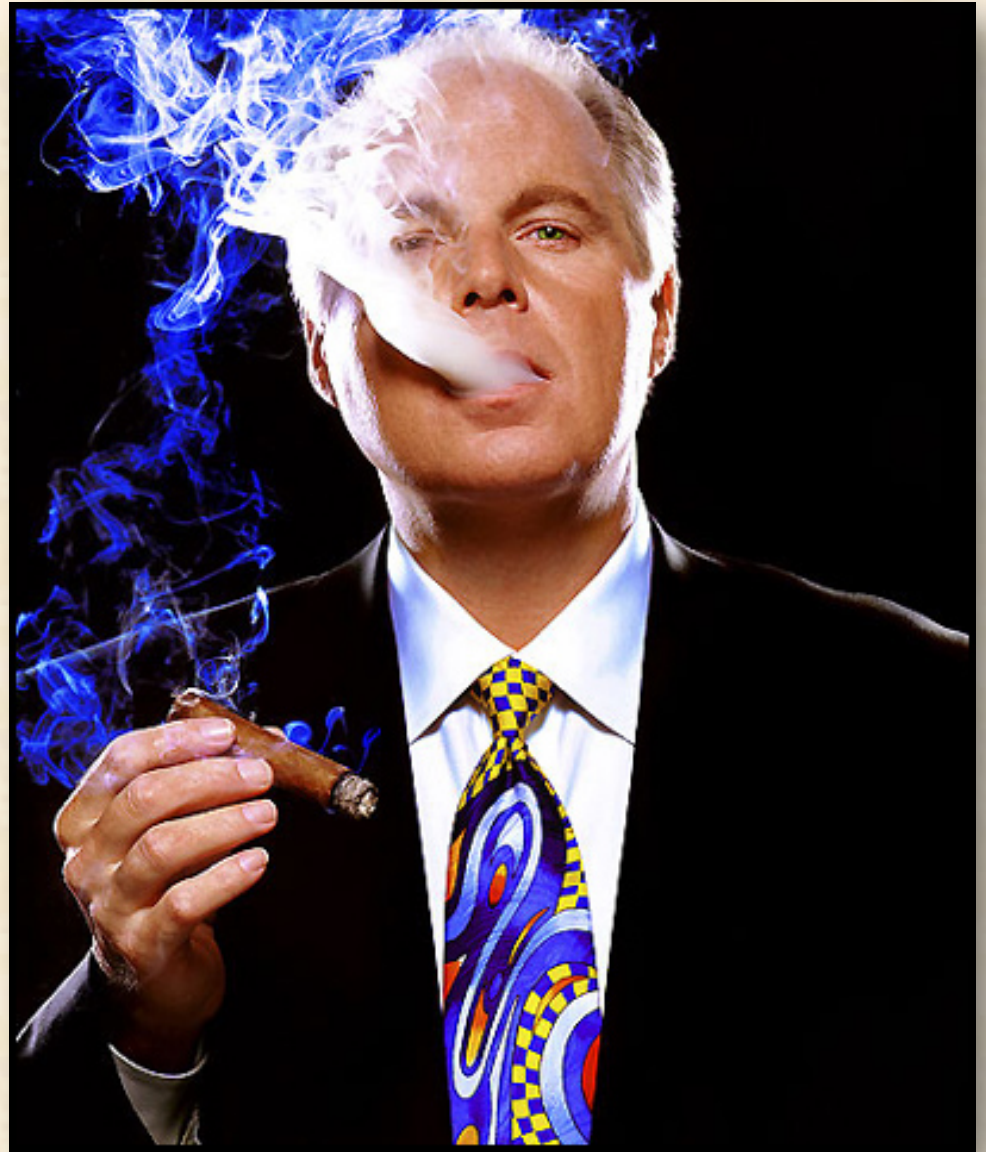


Critical thinking!



Unfortunately...

**“There is no
conclusive proof
that nicotine’s
addictive... And
the same thing
with cigarettes
causing
emphysema, lung
cancer, heart
disease.”**



"My fear is that the whole island (Guam) will become so overly populated that it will tip over and capsize."



Congressman
Hank Johnson



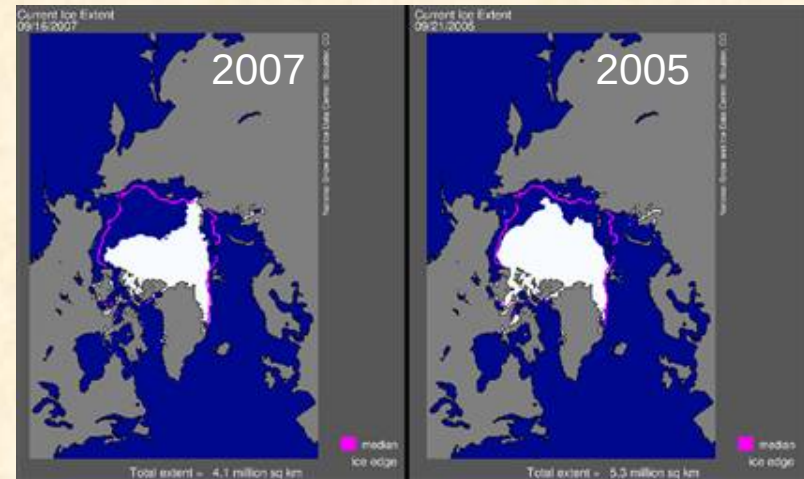
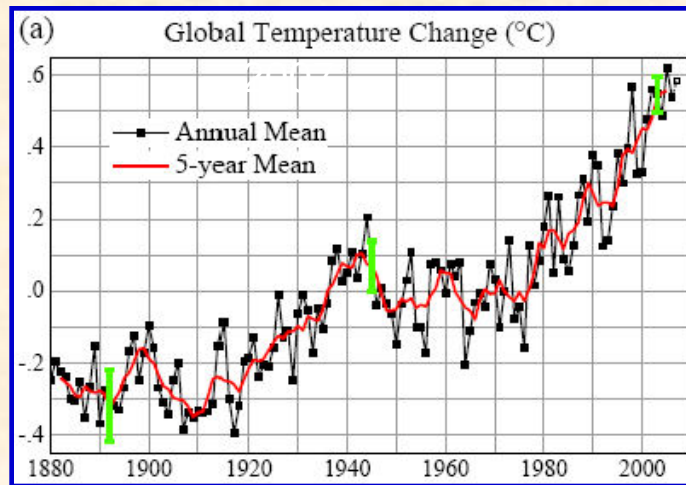


Former Presidential Candidate Michelle Bachmann

Gardasil Vaccine causes mental retardation

“It (the vaccine) comes with very serious consequences. There’s a woman who came up crying to me tonight after the debate. She said her daughter was given that vaccine. She told me her daughter suffered mental retardation as a result of that vaccine.”

In spite of the overwhelming scientific data...



“Global warming is the greatest hoax ever perpetrated on the American people.”

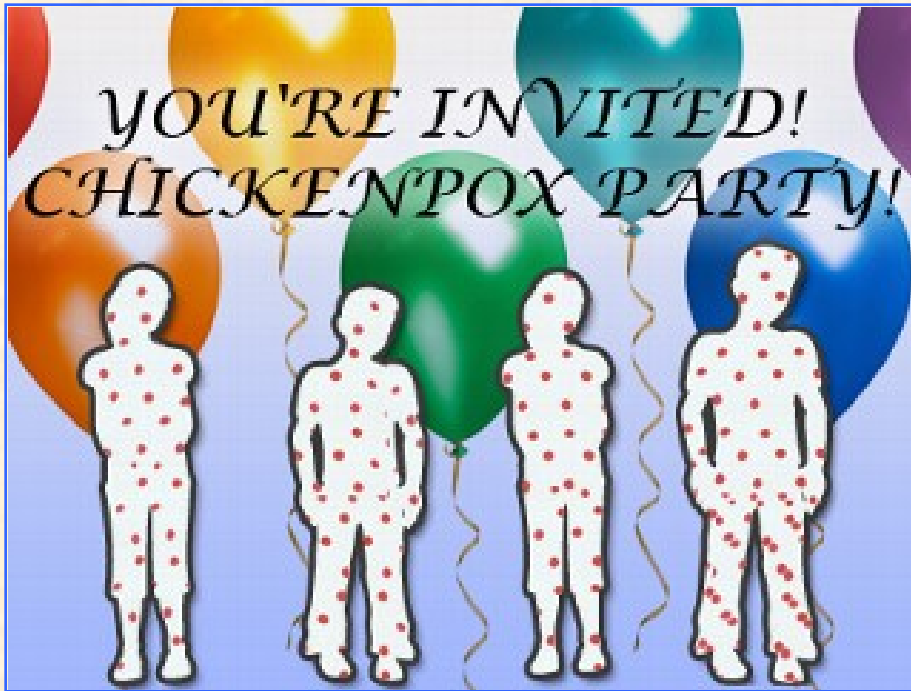


U.S. Sen. James M. Inhofe

"I mean, one of the biggest problems that exists right now in the world is nuclear waste. That's something I've been involved with for a while with a group of scientists — finding a way to **neutralize radiation**, believe it or not."



Personal decisions: Chickenpox parties?



Carrie, a mother from Atlanta, Ga., is one of those parents.

"My 7-year-old daughter has been to six of these parties.

Unfortunately, we have not caught the pox yet, but I'm keeping my eye out for more parties." ABC News Online 2/2/09



**What do
these people
have in
common?**

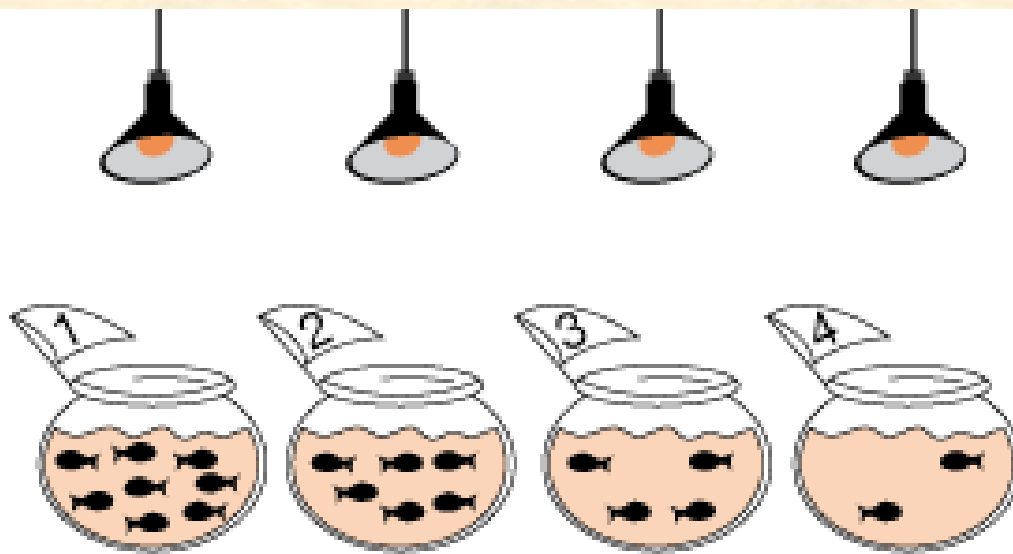


They are all college graduates!



Science and Engineering Indicators (SEI)

- ✓ ~ 44% Americans do not know that it takes the Earth one year to go around the sun.
- ✓ ~ 46% do not know that electrons are smaller than atoms.
- ✓ ~ 67% reject the Big Bang.
- ✓ > 50% reject evolution.
- ✓ < 10% college graduates know what causes the seasons.



50%!

Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	25°C	25°C	25°C	25°C

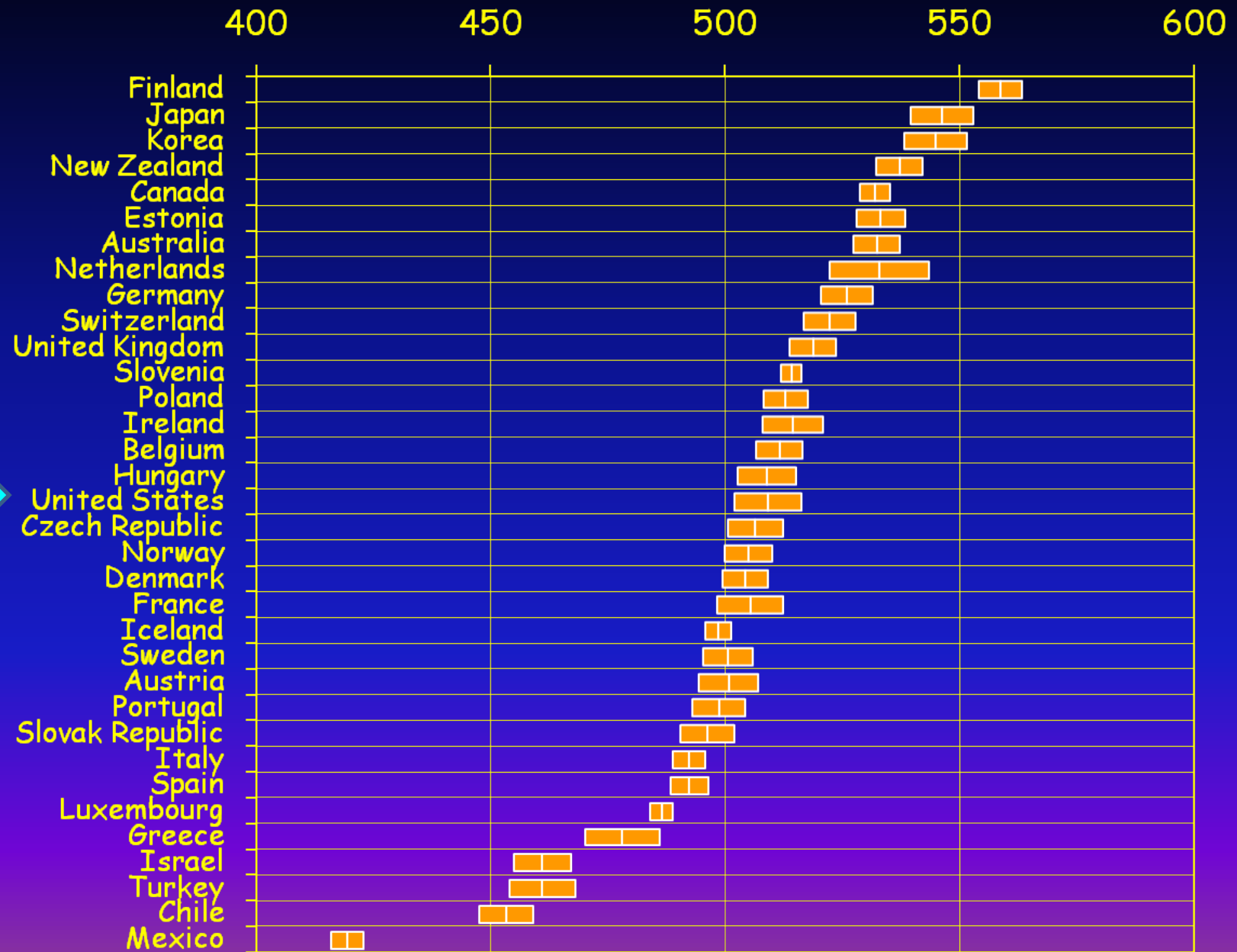
- A) If the # of fish in the fish bowl affects the behavior of the fish.**
- B) If the temperature of the fish bowl affects the behavior of the fish.**
- C) If the temperature and the amount of light affect the behavior of the fish.**
- D) If the # of fish, the temperature, and the amount of light affect the behavior of the fish.**



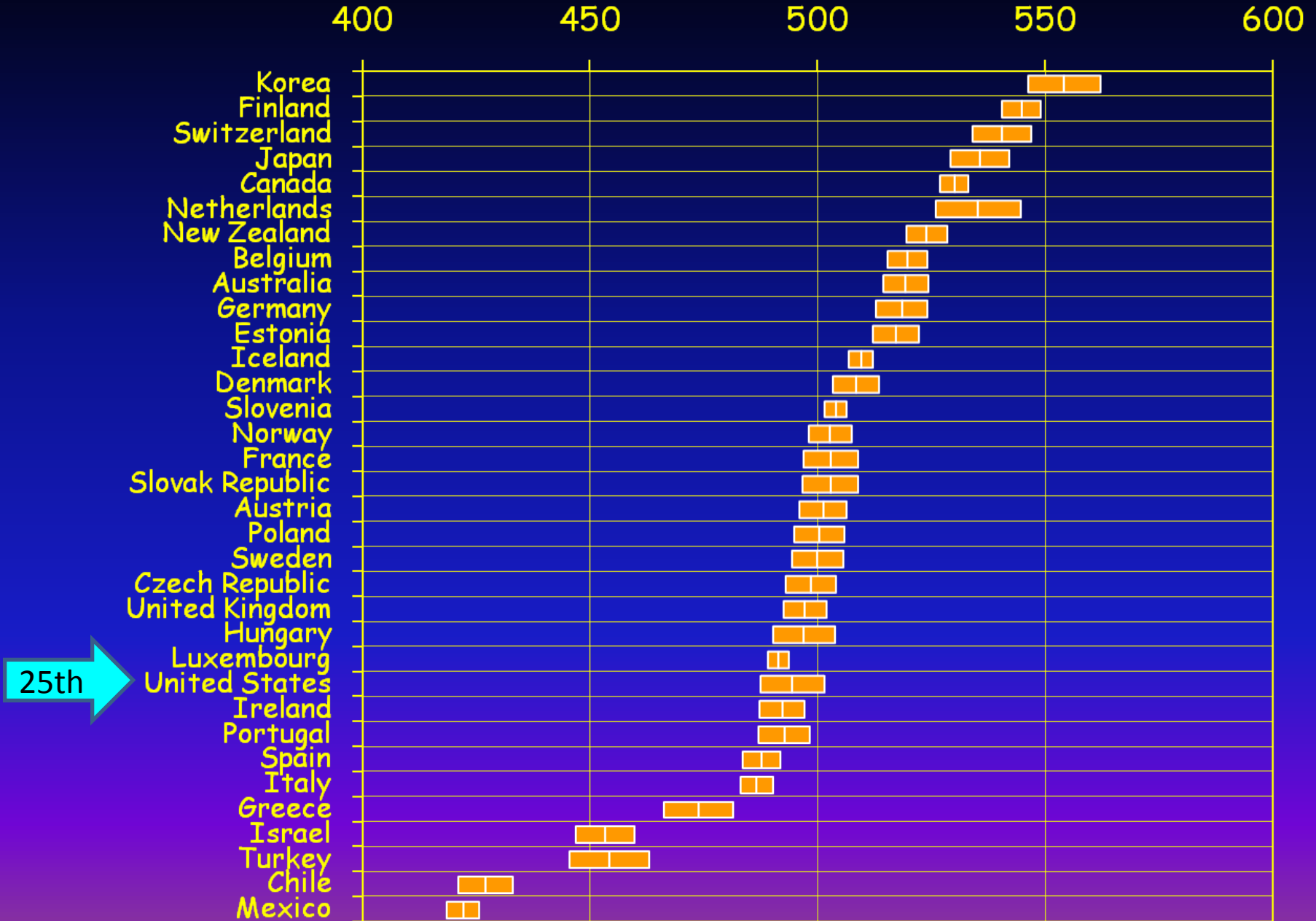
Are our high schools working?

Program for International
Student Assessment (PISA)

PISA Science Results 2009



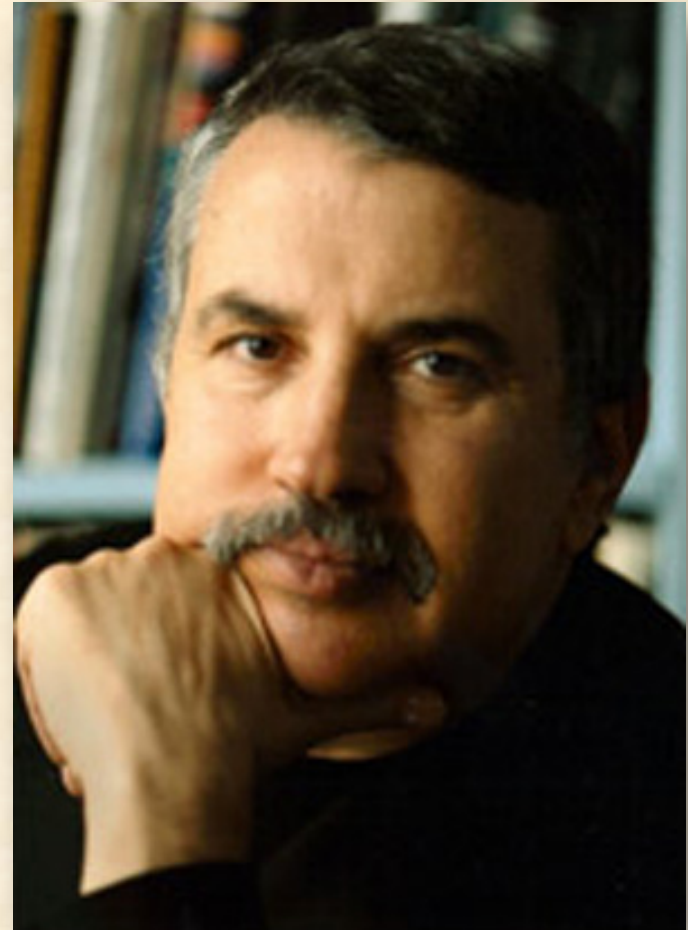
PISA Math Results 2009



International competitiveness?

NY Times columnist Thomas Friedman

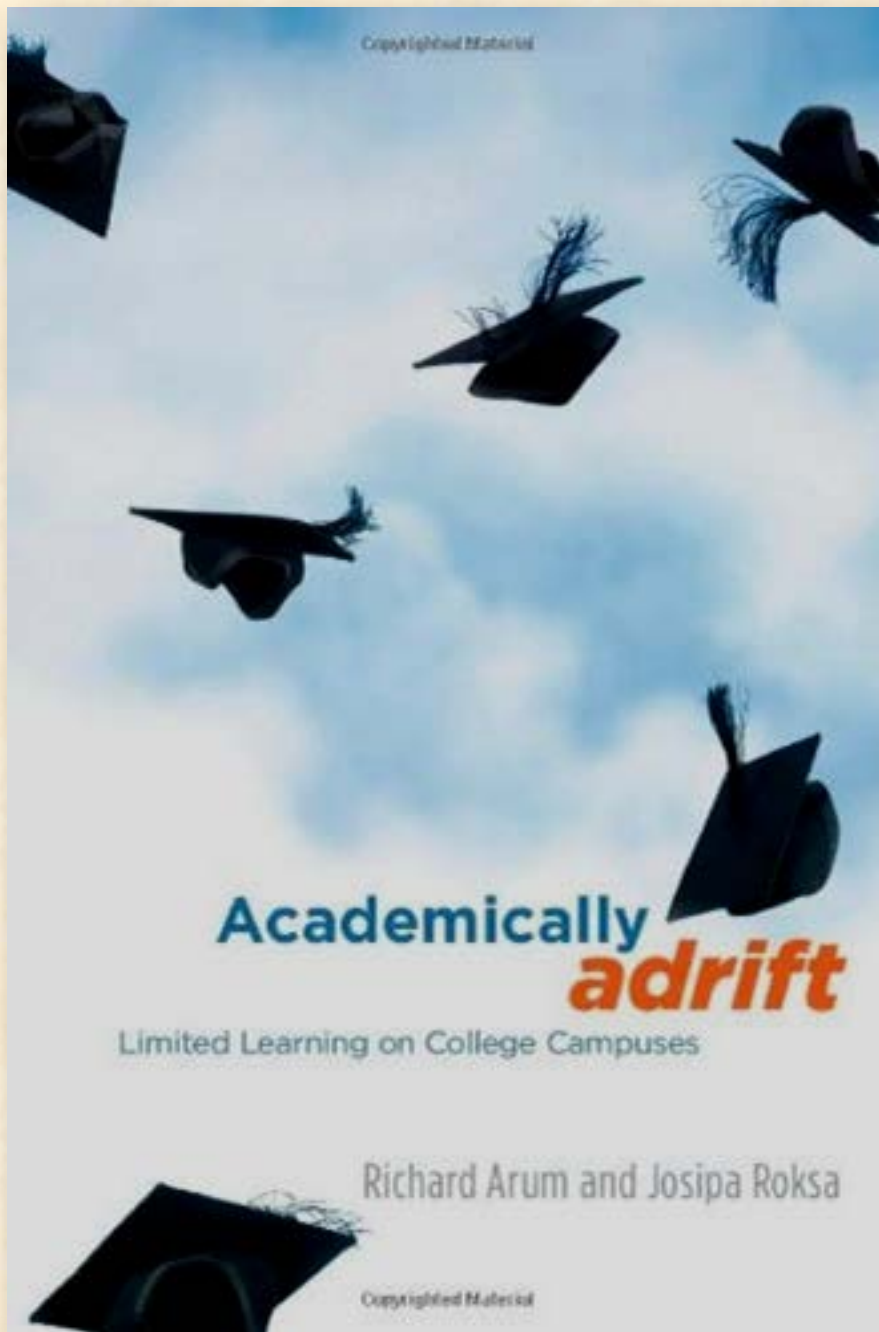
“This puts our average youth on par with those from Portugal and the Slovak Republic, rather than with students in countries that are more relevant competitors for service-sector and high-value jobs, like Canada, the Netherlands, Korea, and Australia.”





Carnegie Institution report:

- ✓ > 93% of American adults are scientifically illiterate.
- ✓ > 78% of college graduates are too.



> 2300 undergrads at 2 dozen universities

* Critical thinking, complex reasoning, writing

* 45% showed no improvement at the end of two years

* 36% ... over 4 years

A Twenty-Year Survey of Science Literacy Among College Undergraduates

By Chris Impey, Sanlyn Buxner, Jessie Antonellis, Elizabeth Johnson, and Courtney King

First results from a 20-year survey of science knowledge and attitudes toward science among undergraduates are presented. Nearly 10,000 students taking astronomy as part of a general education requirement answered a set of questions that overlap a science literacy instrument administered to the general public by the National Science Foundation. The research questions addressed are: What is the level of science literacy among undergraduates, and what variables or attributes predict science literacy? Their attitudes toward science and pseudo-science were probed by a set of 22 statements coded on a Likert scale. On the knowledge items, freshmen perform only marginally higher than the general public, with the exception of large positive differences in their knowledge of evolution and the Big Bang. Science majors



Anyone who teaches undergraduate science plays an important role in our society. If they teach science majors, they fulfill the need for a technically

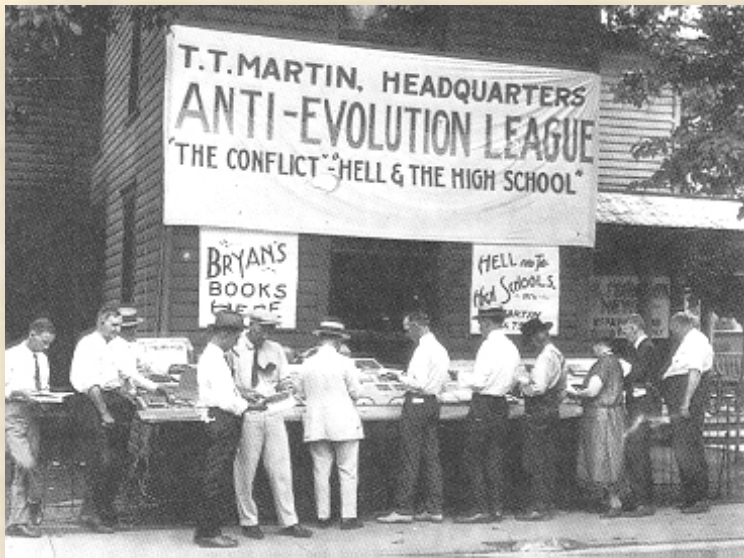
overall. The National Academy of Scholars surveyed science curricula used in bachelor of arts degrees from the top 50 institutions ranked by the U.S. News and World Report; the

Journal of College Science Teaching,
April 2011, Volume 40: 31-37

2-3 science
classes:

10% ↑ SEI

Little Δ in
**pseudo-
scientific
beliefs!**



reaping what we sow



What are we doing wrong?





Bruce Alberts is Editor-in-Chief of *Science*.

Scientists may tend to blame others for the problem – but strange as it may seem—we have done more than anyone else to create it.

Redefining Science Education

THERE IS A MAJOR MISMATCH BETWEEN OPPORTUNITY AND ACTION IN MOST EDUCATION SYSTEMS today. It revolves around what is meant by “science education,” a term that is incorrectly defined in current usage. Rather than learning how to think scientifically, students are generally being told about science and asked to remember facts. This disturbing situation must be corrected if science education is to have any hope of taking its proper place as an essential part of the education of students everywhere.

Scientists may tend to blame others for the problem, but—strange as it may seem—we have done more than anyone else to create it. Any objective analysis of a typical introductory science course taught today in colleges and universities around the world, whether it be biology, chemistry, physics, or earth sciences, would probably conclude that its purpose is to prepare students to “know, use, and interpret scientific explanations of the natural world” (strongly emphasizing the “know”). This is but one of four goals recommended for science education by the distinguished committee of scientists and science education experts convened by the U.S. National Academies that produced *Taking Science to School: Learning and Teaching Science in Grades K-8*. And yet college courses set the model for the teaching of science in earlier years.

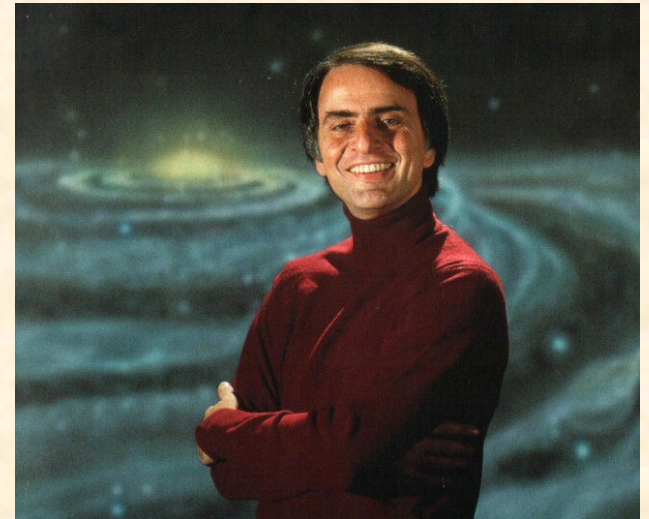
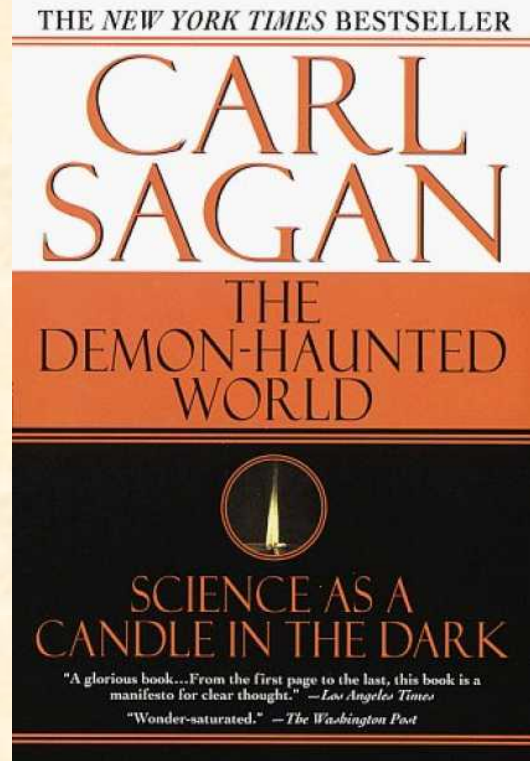
The three other goals of equal merit and importance are to prepare students to generate and evaluate scientific evidence and explanations, to understand the nature and development of scientific knowledge, and to participate productively in scientific practices and discourse (summarized in the Academies’ *Ready, Set, Science!*). Scientists would generally agree that all four types of science understanding are critical not only to a good science education but also to the basic education of everyone in the modern world. Why then do most science professors teach only the first one?

As the scientist and educator John A. Moore emphasized in his pro-



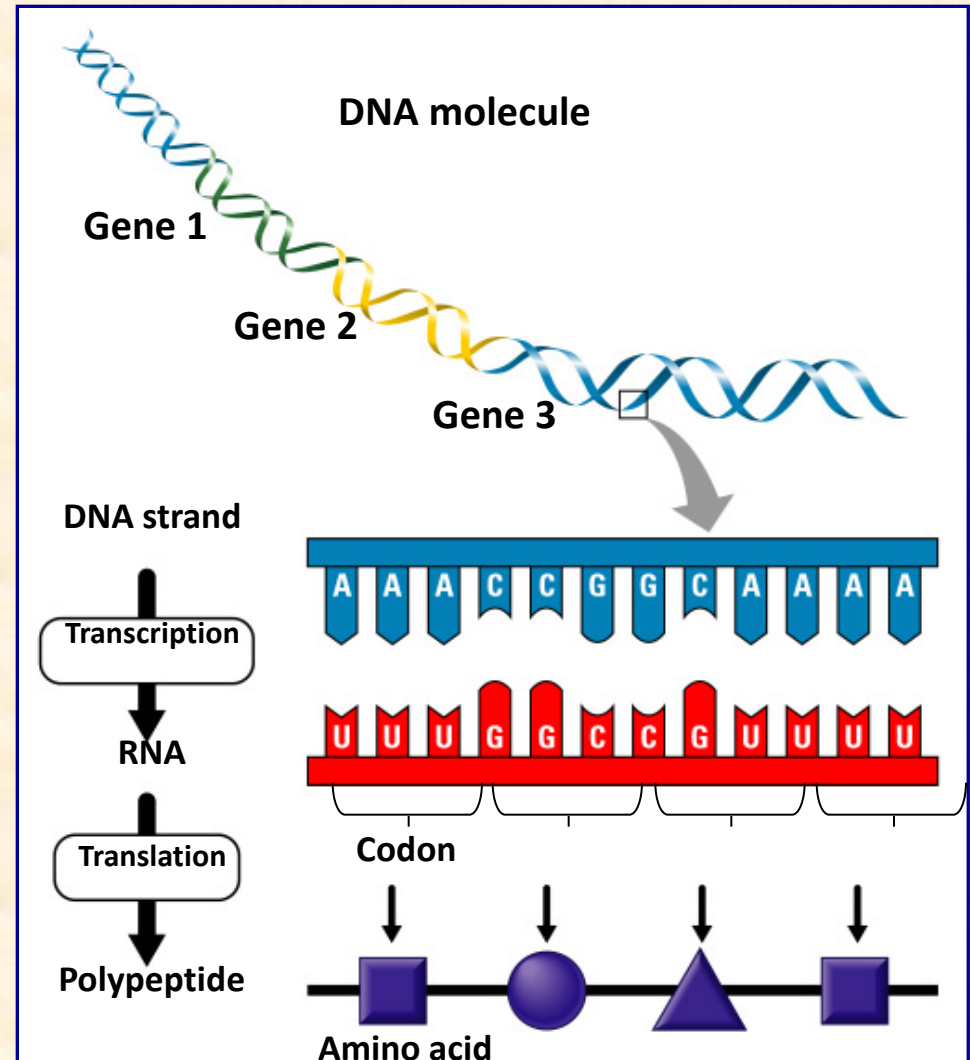
Tend to focus on facts – not the nature and methods of science or critical thinking.

“If we teach only the findings and products of science – no matter how useful and even inspiring they may be – without communicating its critical method, how can the average person possibly distinguish science from pseudoscience? ... The method of science ... is far more important than the findings of science.”

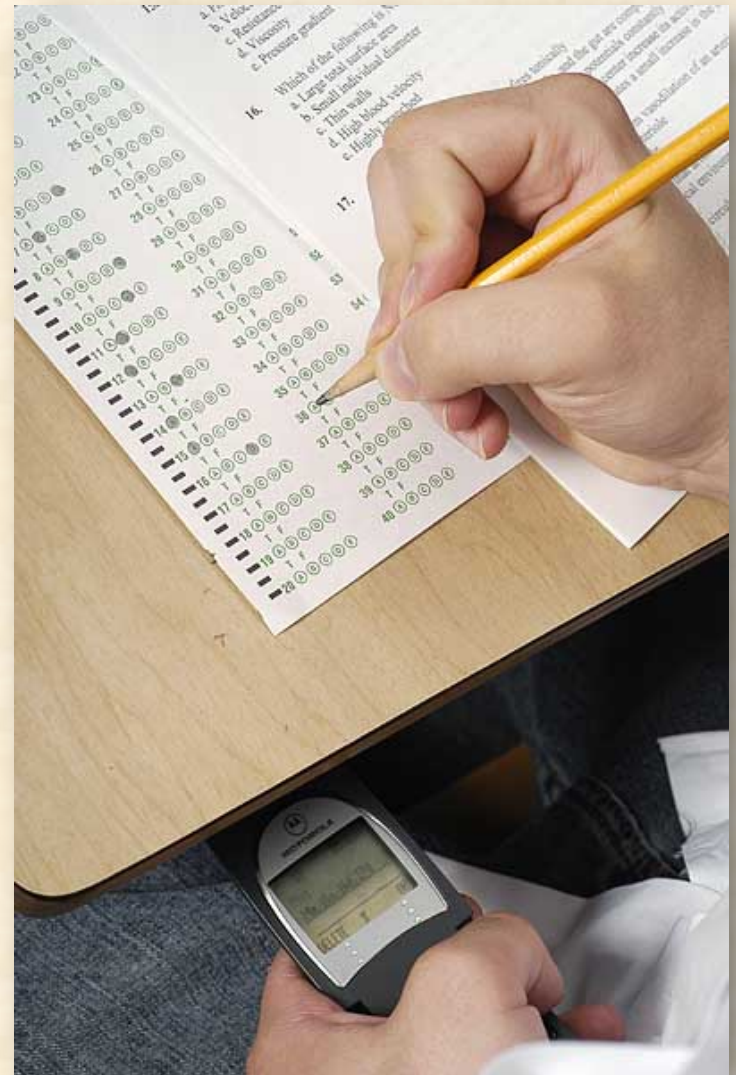


Transcription & translation: the “language” metaphor

- What is the language of nucleic acids?
 - In DNA, it is the linear sequence of nucleotide bases



Exam!



My kids hate
math and science...

and so do I!





Bloom's Taxonomy

Evaluation

Synthesis

Analysis

Application

Comprehension

Information (rote retention)

Critical Thinking

Not So



“It is much easier to test for the facts of science than it is to test for the other critical types of science understanding.....”

Bruce Alberts, *Redefining Science Education*, 2009

Sam Houston State's solution



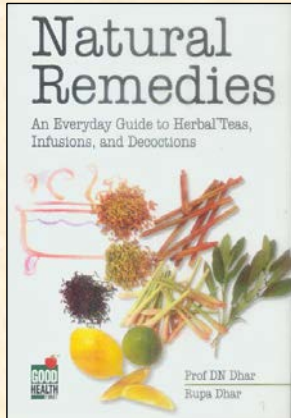
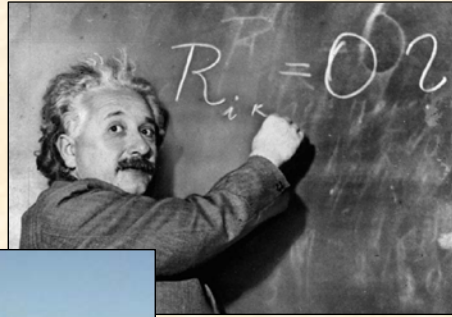
Quality Enhancement Plan

**Foundations of Science:
Improving Scientific Reasoning Among Non-Science Majors**

Submitted By
Sam Houston State University
February, 2009

A Member of The Texas State University System

Foundations of Science



Integrated Science course

- ✓ Science as a way of knowing
- ✓ Improve critical thinking skills
- ✓ The importance of evidence and logic
- ✓ Engender scientific habits of mind

Why does science and CT matter?

Witches!





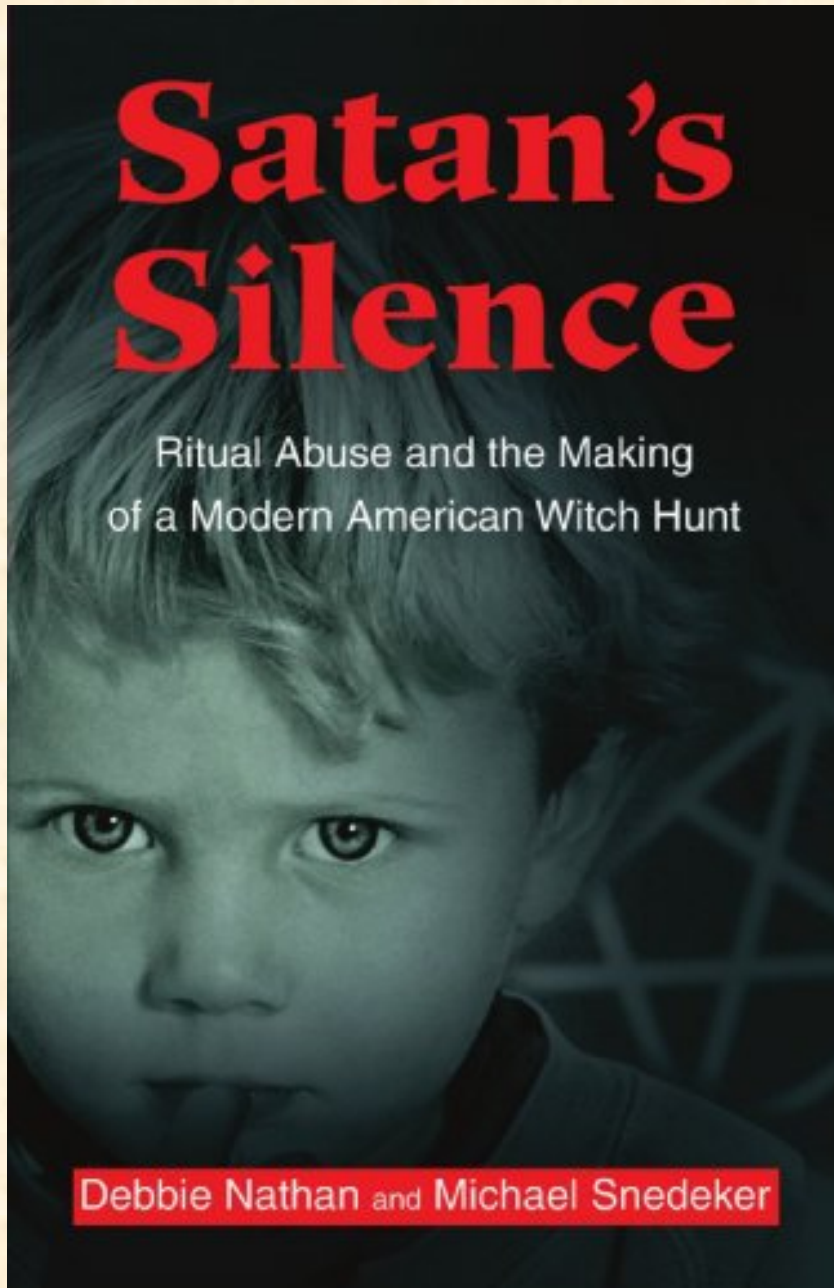
Burned at the stake



A thing of the past?

Unfortunately no





Satanic Ritual Abuse: a modern day witch hunt

Between 1984-1995:

- **185 adults charged with ritual abuse**
- **113 were convicted**
- **many convictions overturned**
- **several still in jail**



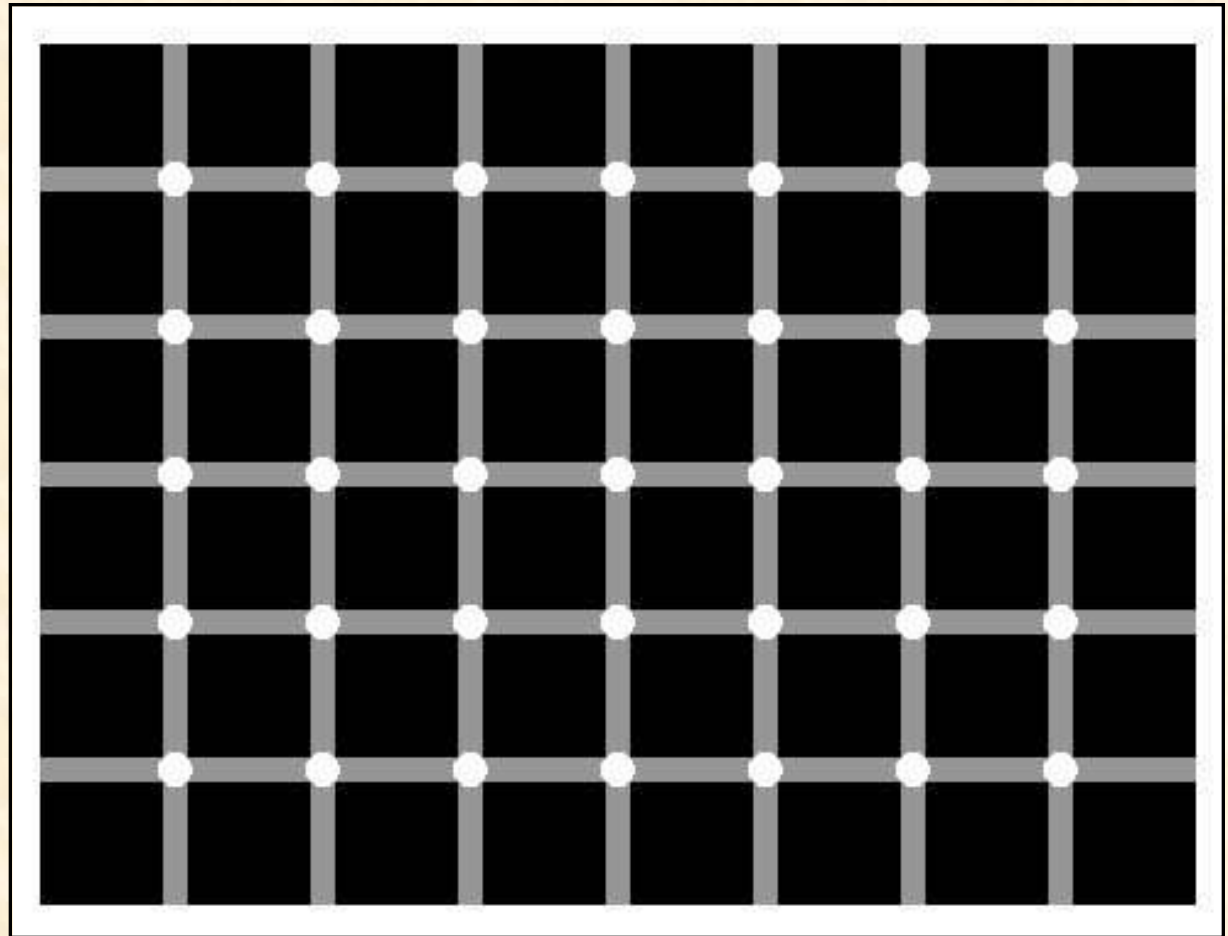
- ✓ understanding the world
- ✓ evidence
- ✓ multiple working hypotheses

Why a scientific approach to knowledge is important.

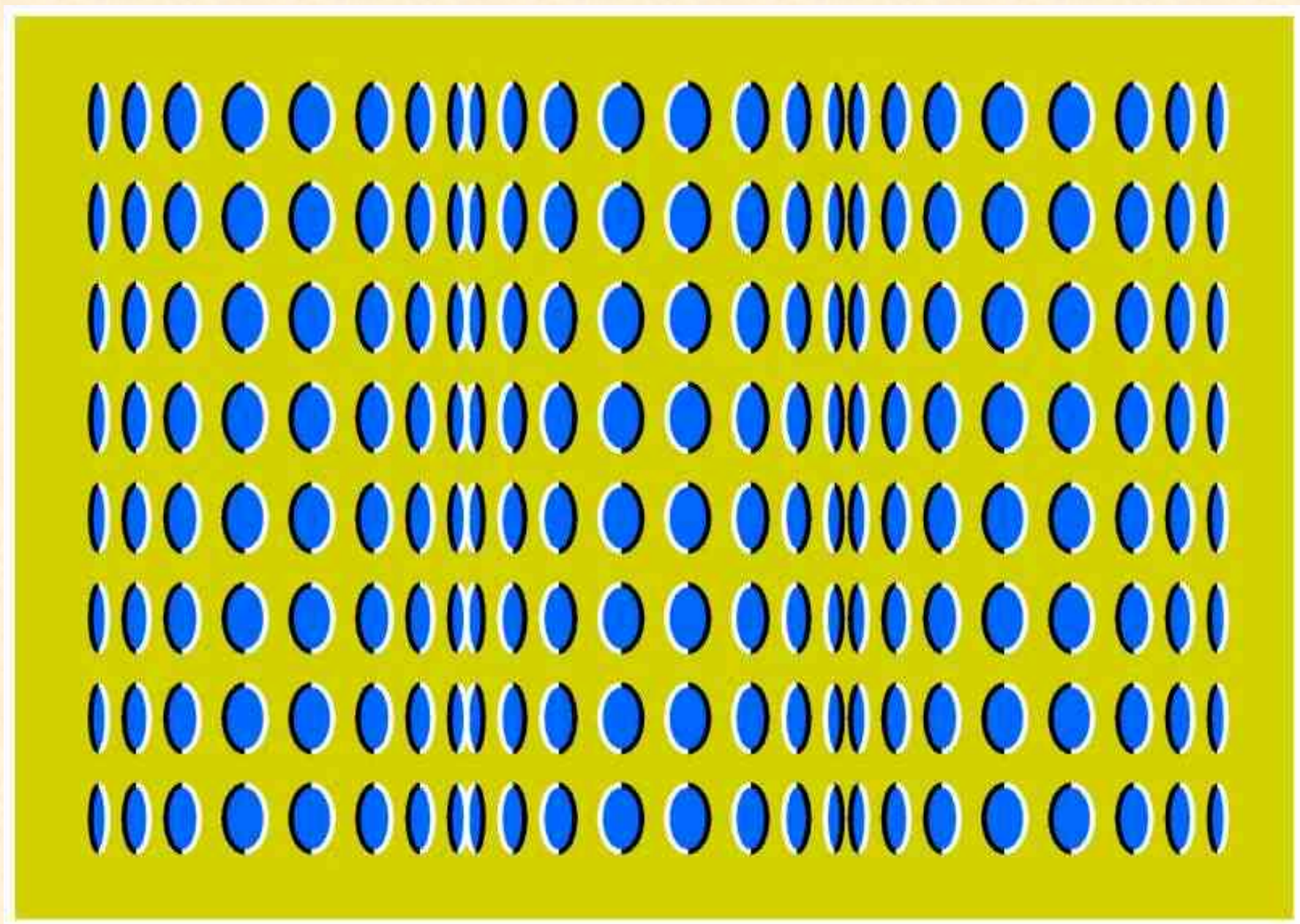


Why anecdotes don't count in science:

**Errors in
Perception,
Memory, and
Reasoning**



***The scientific method is a way of minimizing
errors based on evidence and CT***



Facilitated Communication

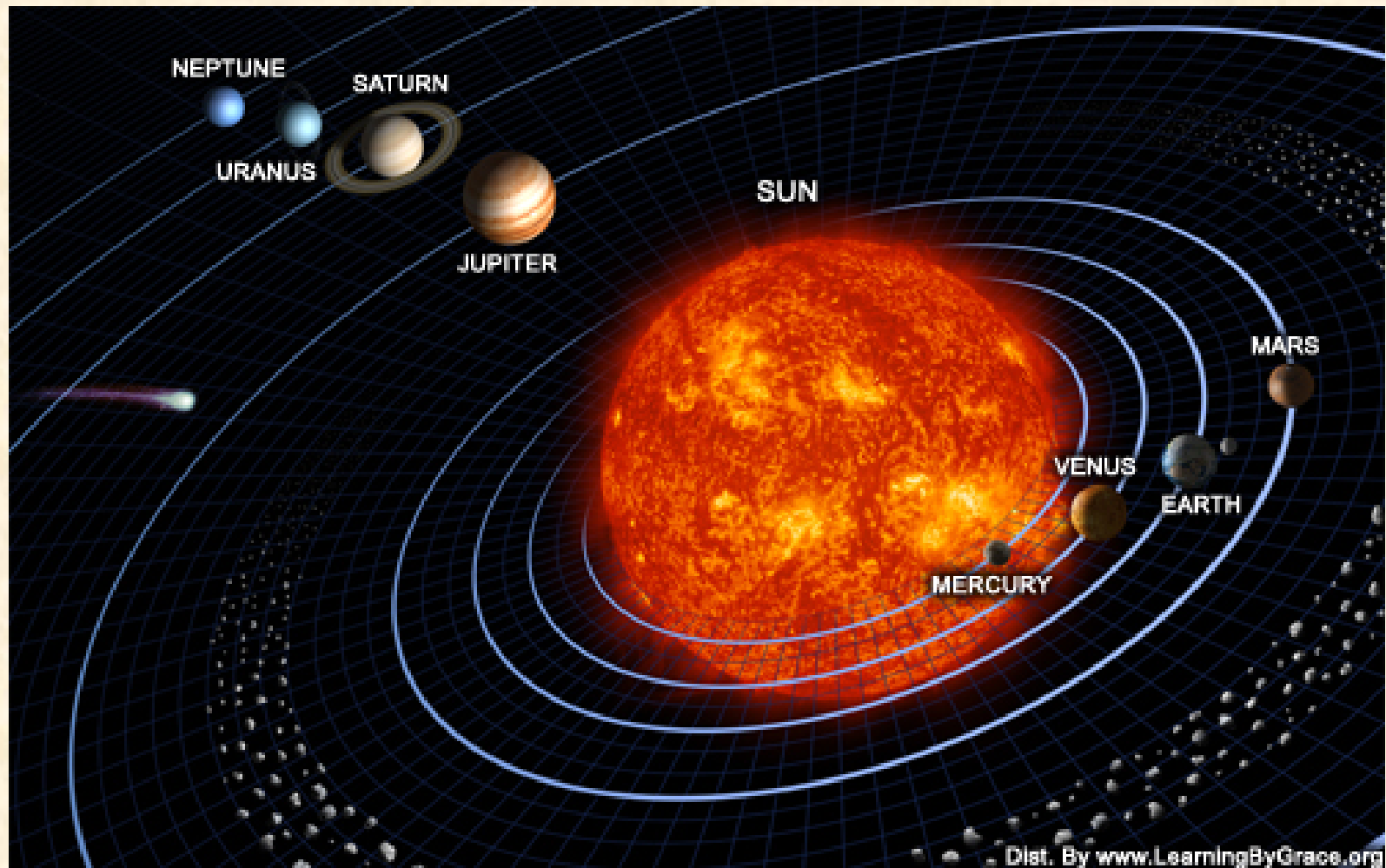
examples of bad science



confirmation bias

double-blind studies

the history of significant ideas



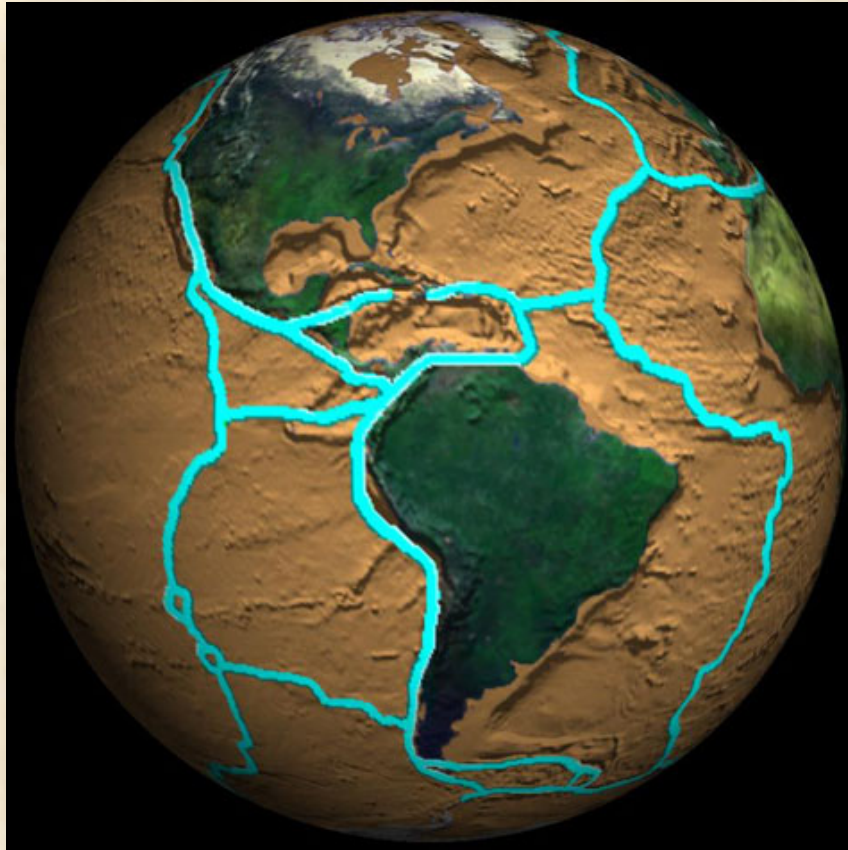
science is self-correcting

We use extraordinary claims to hold the students' attention...



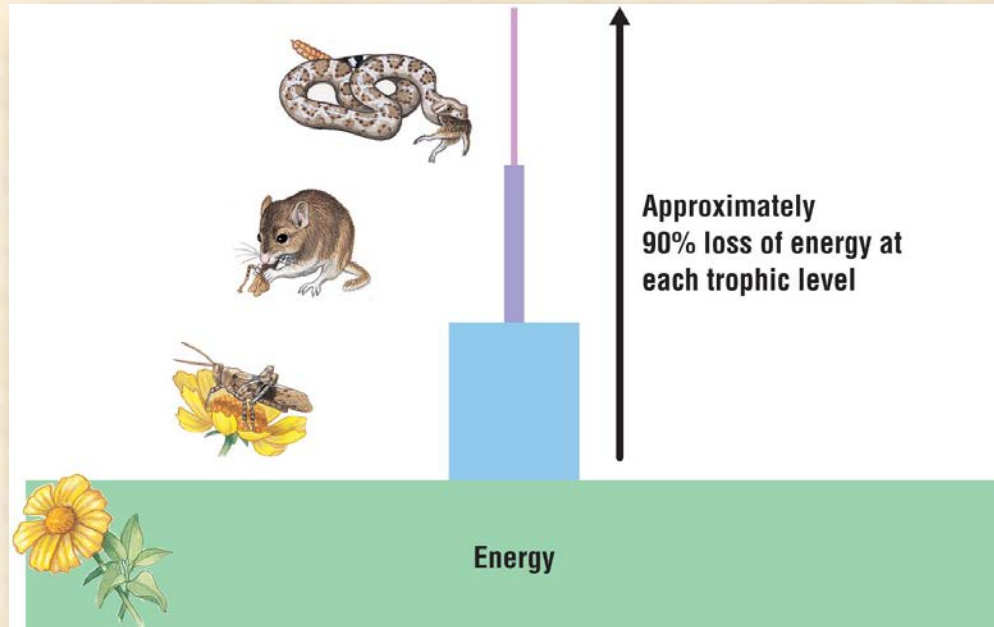
...but they still learn, and use, a good deal of scientific content.

**We use extraordinary claims to hold
the students' attention...**



**...but they still learn, and use, a good
deal of scientific content.**

We use extraordinary claims to hold the students' attention...



...but they still learn, and use, a good deal of scientific content.

Our 'Working' Definition of CT

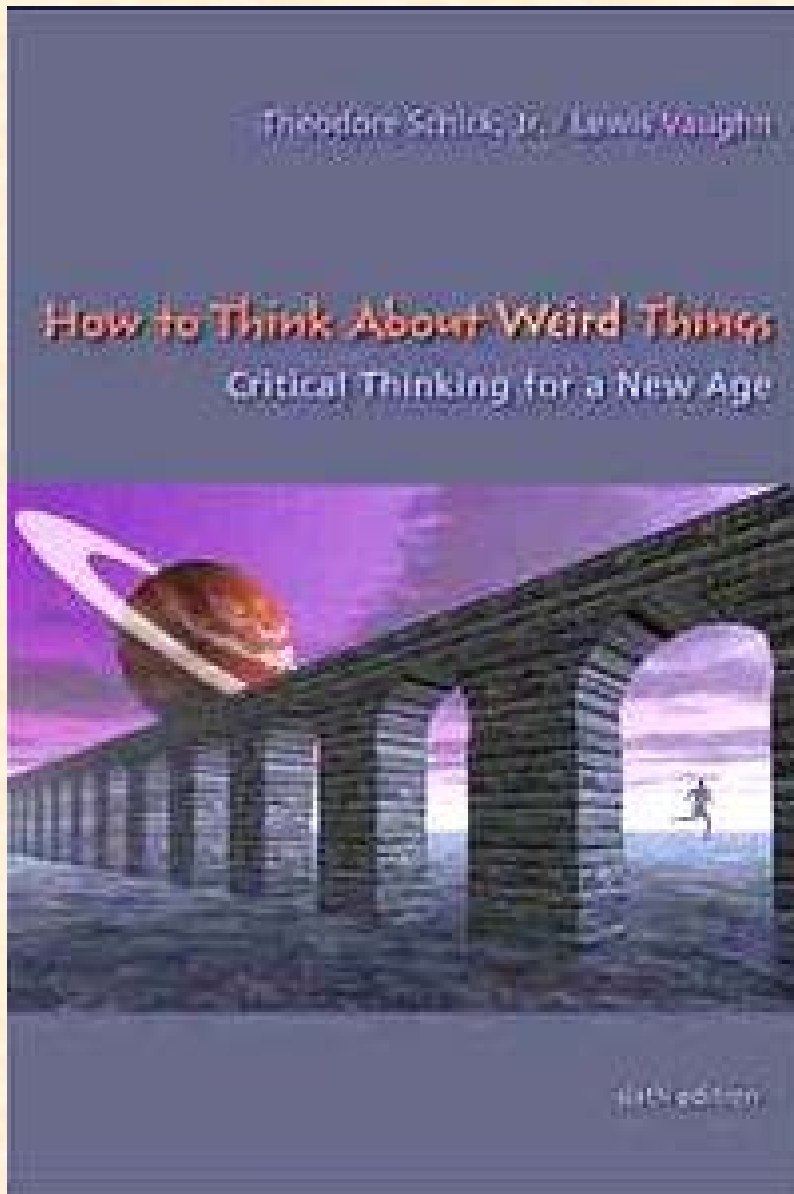
**The process of logically evaluating the validity
of claims on the basis of well-supported
evidence.**

Drawing reasonable conclusions based on the
evidence available.



It includes asking the following 5 questions:

- (a) ***What** am I being asked to believe or accept?*
- (b) ***What evidence** is available to support the assertion?*
- (c) *What **alternative explanations** might there be for the phenomenon?*
- (d) ***What evidence** is there in support of the alternatives?*
- (e) *What conclusions are **most reasonable** based on the evidence and the number of alternative explanations?*



Textbook that
focuses on CT

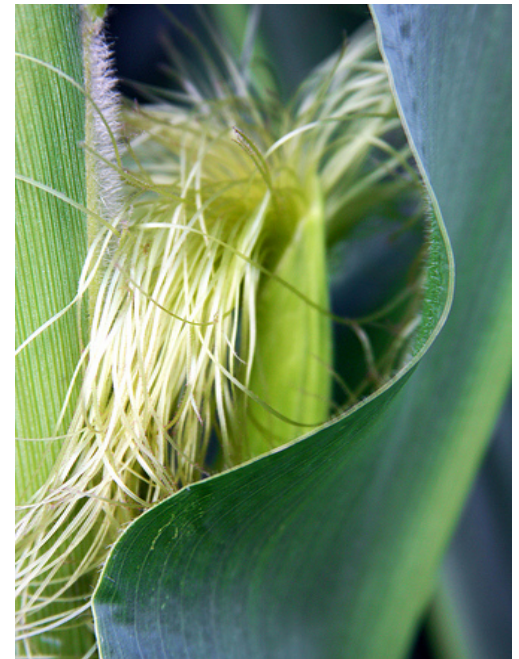
Theodore Schick and Lewis Vaughn

Examples of FoS Questions

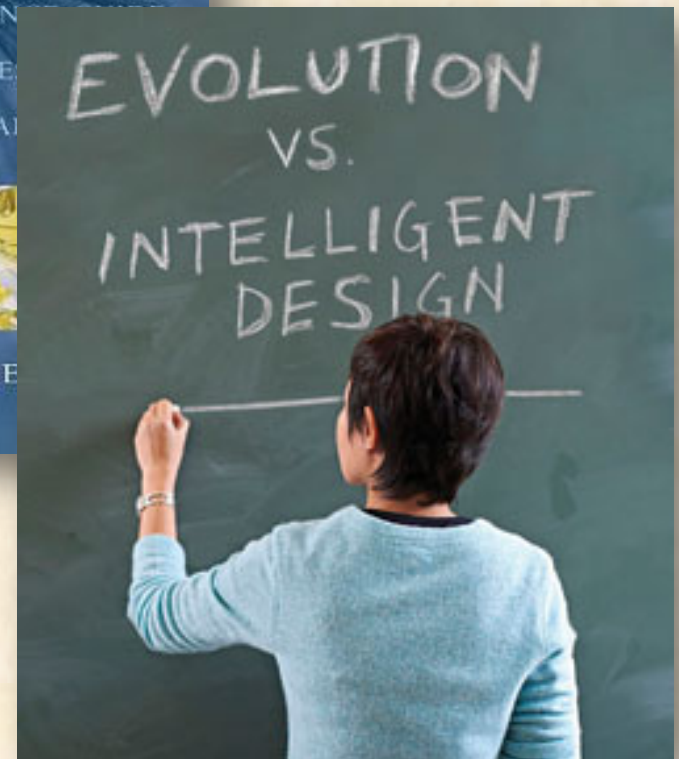
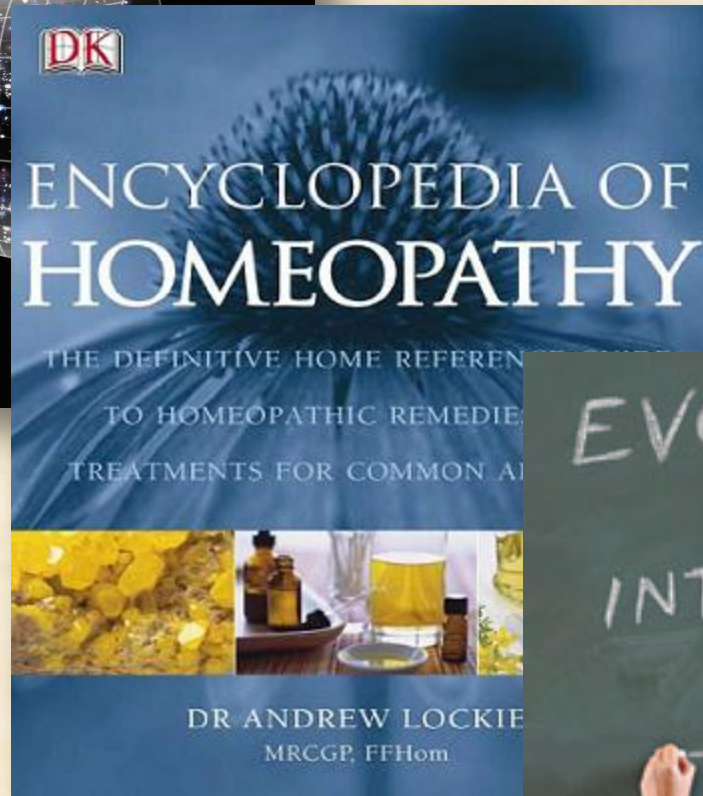
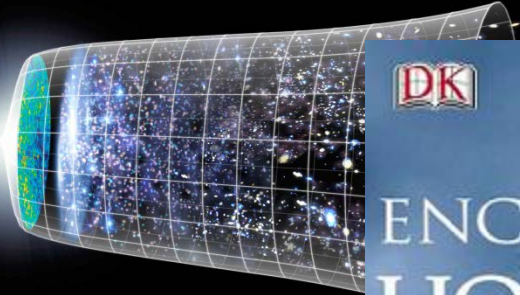
- Megan believes that eating corn silk from a corn plant (like that shown below) will improve the strength and luster of her hair because the corn silk *looks like* hair.

What logical fallacy has Meagan committed?

- a. appeal to ignorance
- b. post hoc ergo propter hoc (false cause)
- ★ c. faulty analogy
- d. argument from ignorance
- e. none of the above – her logic is correct



Big Bang



Why facts and CT are both necessary:

Reason well, but **don't know facts** = *wrong answer*

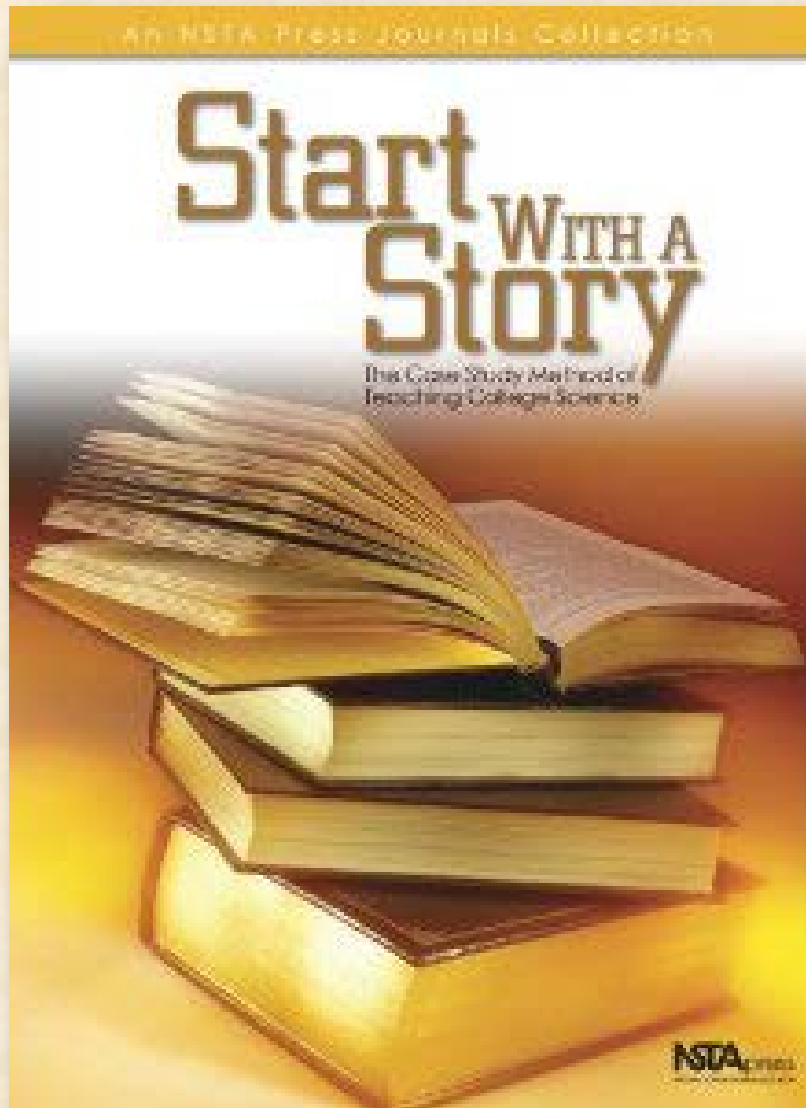
And, if:

Know facts, but can't reason with them and can't organize them in a *meaningful way* = *wrong answer*.

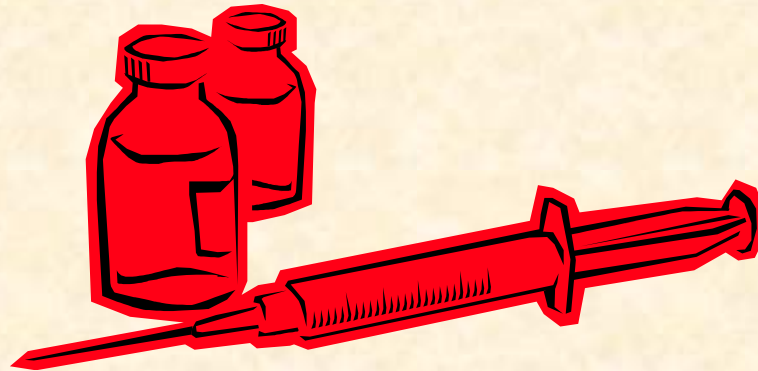
Reasoning made sense – but facts were wrong.



Case studies & Team-based Learning



“Tragic Choices: Autism, Measles, and the MMR Vaccine”

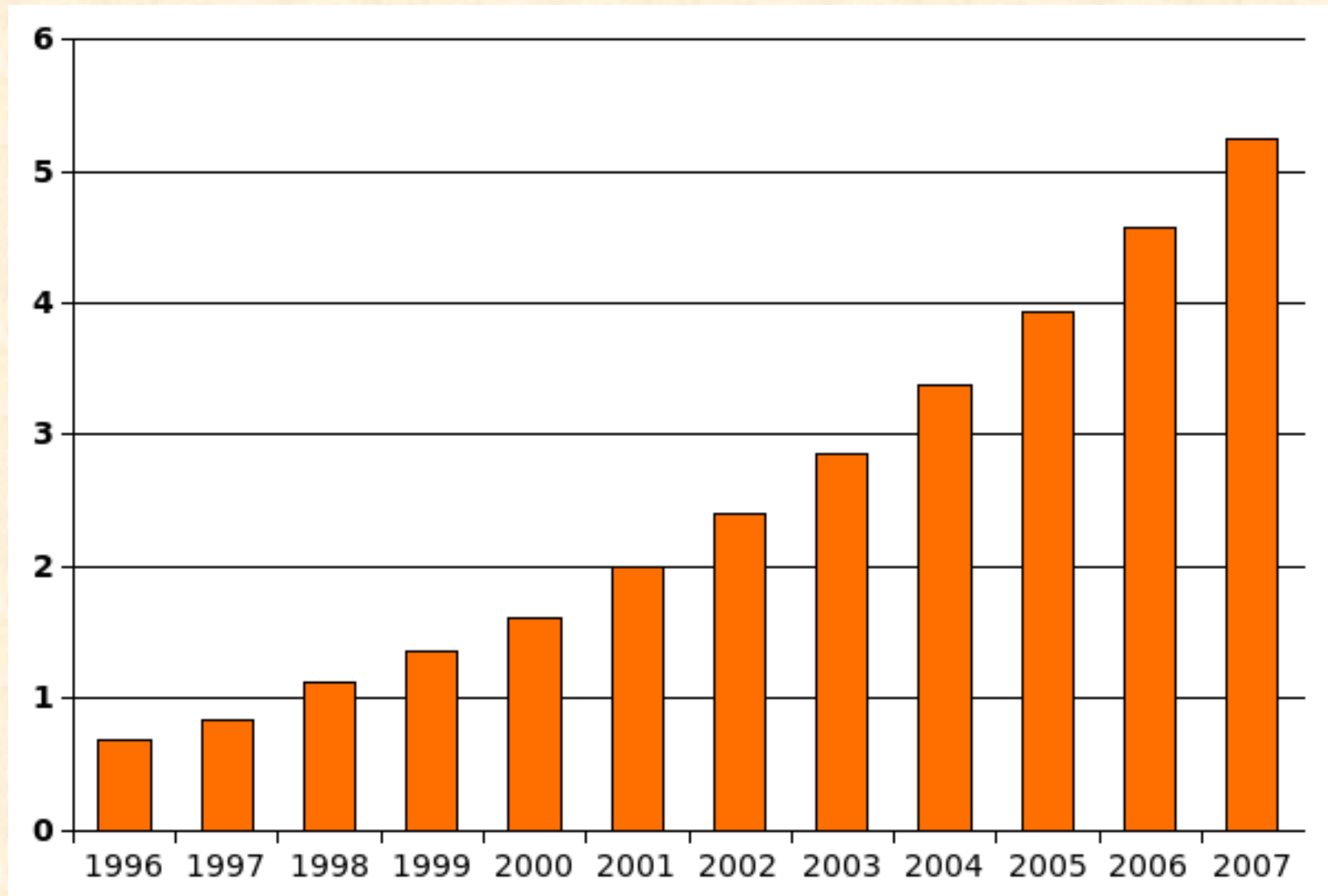






Prevalence of autism in the United States 1996-2007

(cases per 1,000 children age 6-17)



graphic by Eubulides/Wikipedia



And here are
the data from
the scientist in
Great Britain
(Andrew
Wakefield)
referenced by
Carly.

Table 1: Neuropsychiatric diagnosis and interval post MMR vaccination.^a

Child	Behavioural diagnosis	Exposure identified by parents or doctor	Interval from exposure to symptoms
1	Autism	MMR	1 week
2	Autism	MMR	2 weeks
3	Autism	MMR	48 h
4	Autism? Disintegrative disorder?	MMR	Dramatic deterioration immediately after MMR booster at 4.5 years
5	Disintegrative disorder	None-but MMR at 16 months	Self-injurious behavior started at 18 months
6	Autism	MMR	1 week
7	Autism	MMR	24 h
8	Post-vaccinal encephalitis?	MMR	2 weeks
9	Austistic spectrum disorder	Recurrent otitis media	1 week (MMR 2 months previously)
10	Post-viral enchphalitis?	Measles (previously vaccinated with MMR)	24 h
11	Autism	MMR	1 week
12	Autism	None-but MMR at 15 months	Developmental deterioration noted at 16 months

^aTaken from Table 2 in Wakefield *et al.* (1998) Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children. *Lancet* 351:637-641

.... groups then share their ideas





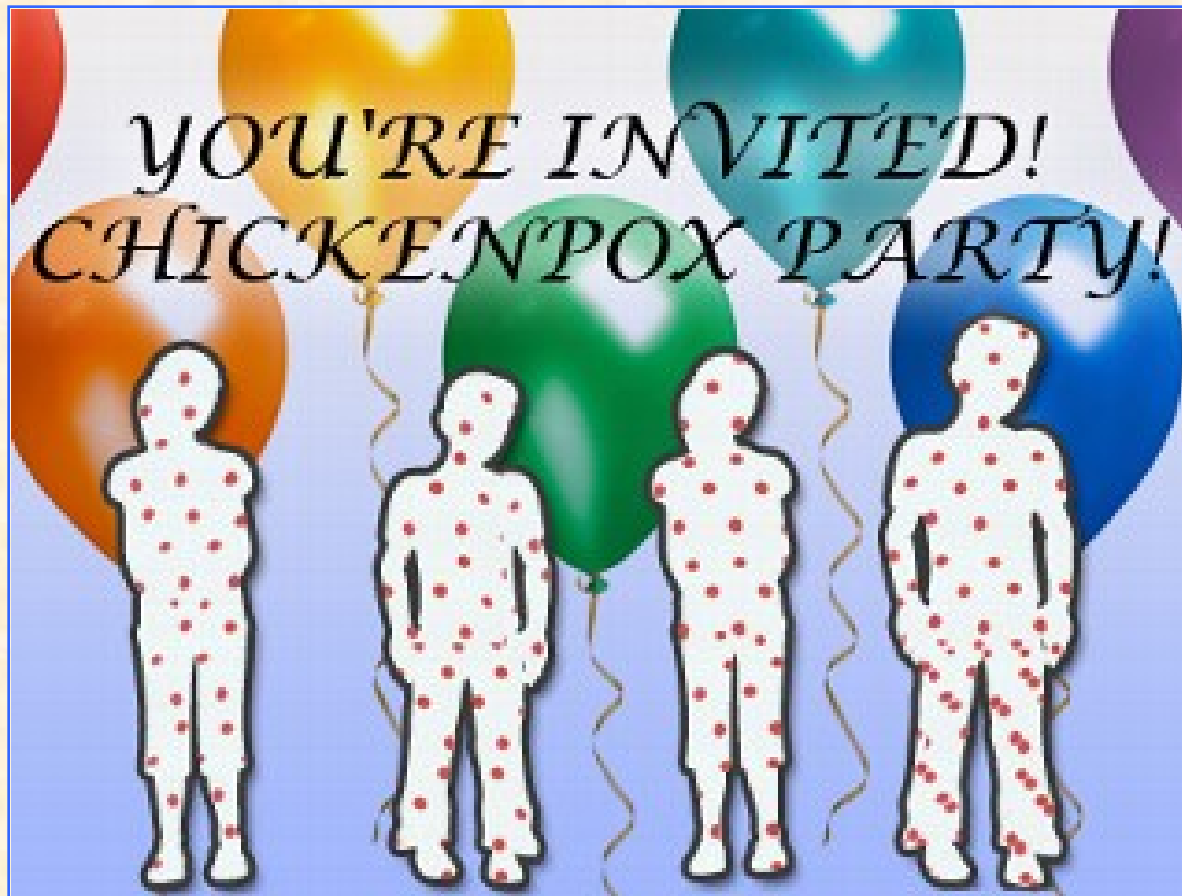
Madsen, K.M. et al. 2002. A population-based study of measles, mumps, rubella vaccination and autism. *The New England Journal of Medicine* 347: 1477-1482.

Sample size: 537,303 children

✓ MMR vaccinated: 440,655

✓ Not MMR vaccinated: 96,648

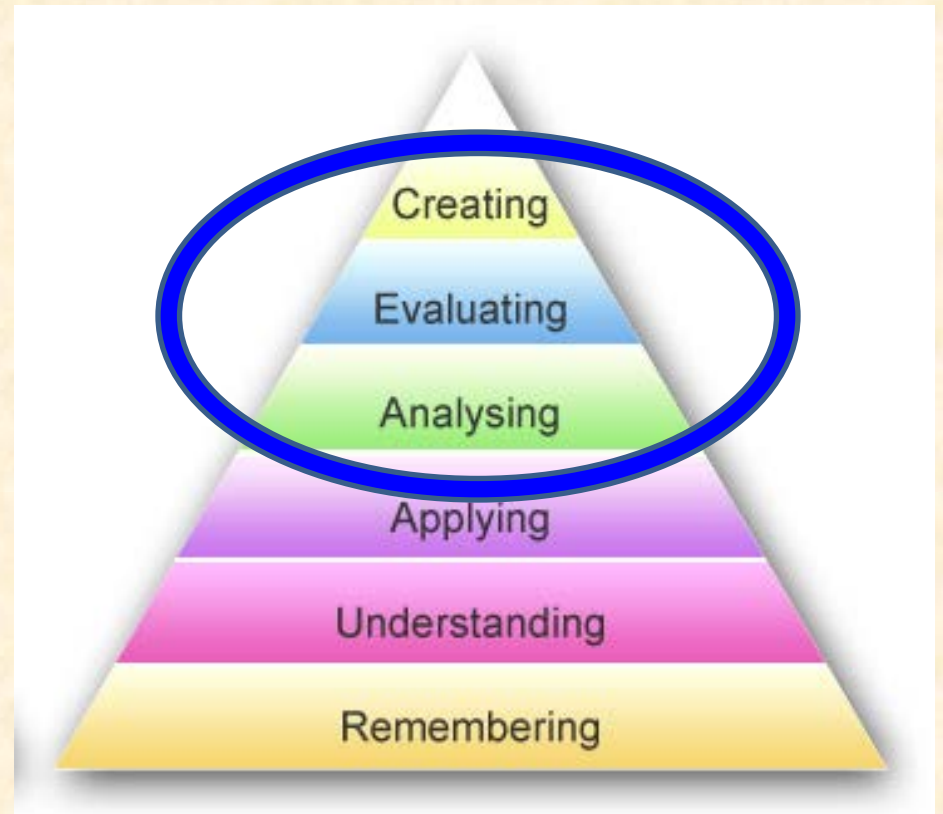
No difference in relative risk of autism among the groups.



✓ thinking “scientifically” is learnable and important



**Have we been
successful?**





Center for Assessment and Improvement of Learning



Critical Thinking and Assessment Test CAT

pre-test

post-test

Sample Disclosed Question

A scientist working at a government agency believes that an ingredient commonly used in bread causes criminal behavior. To support his theory the scientist notes the following evidence.

- 99.9% of the people who committed crimes consumed bread prior to committing crimes.
- Crime rates are extremely low in areas where bread is not consumed.

Do the data presented by the scientist strongly support their theory? Yes **30%** No _____

Are there other explanations for the data besides the scientist's theory? If so, describe.

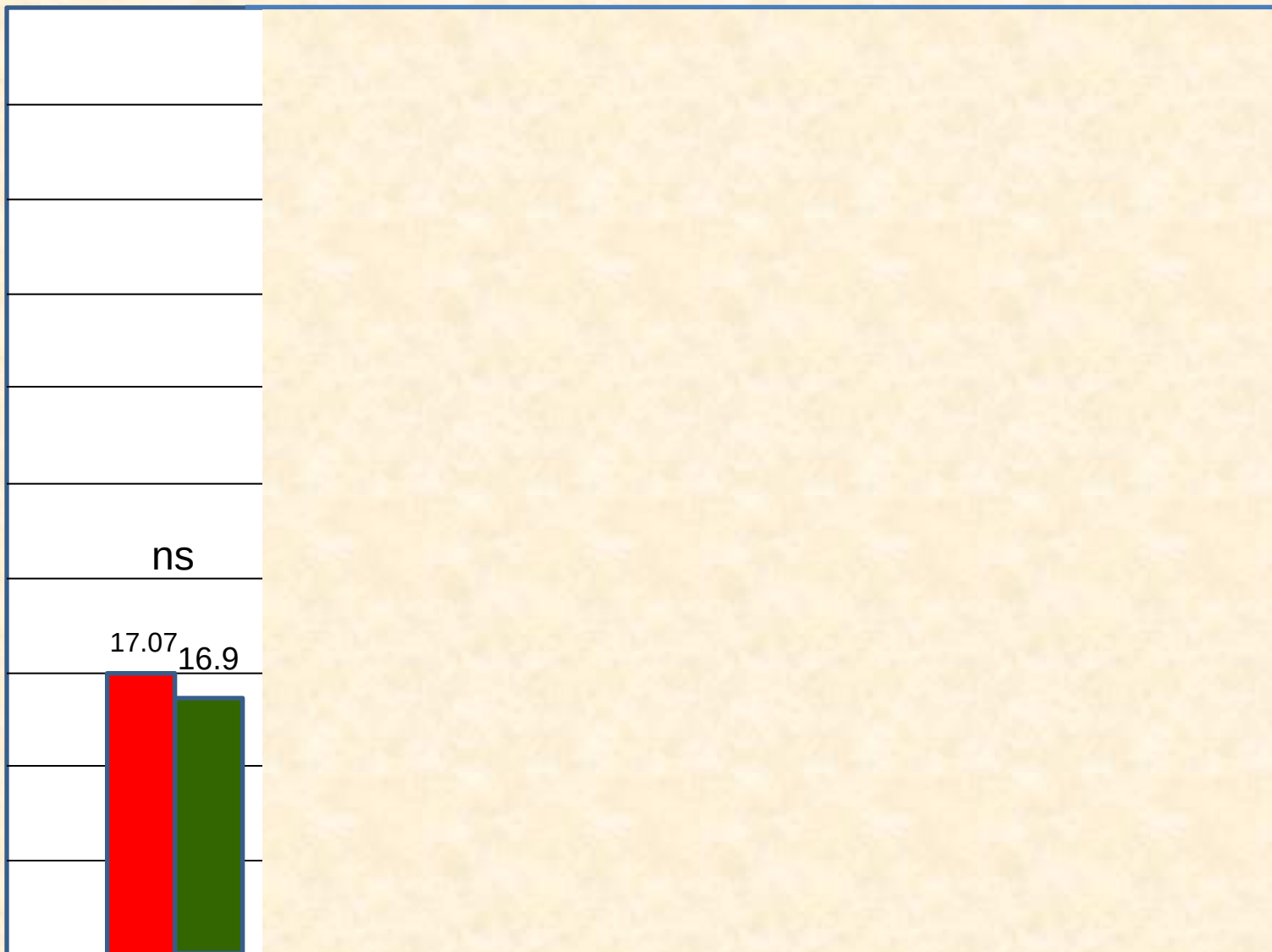
What kind of additional information or evidence would support the scientist's theory?



CAT Score

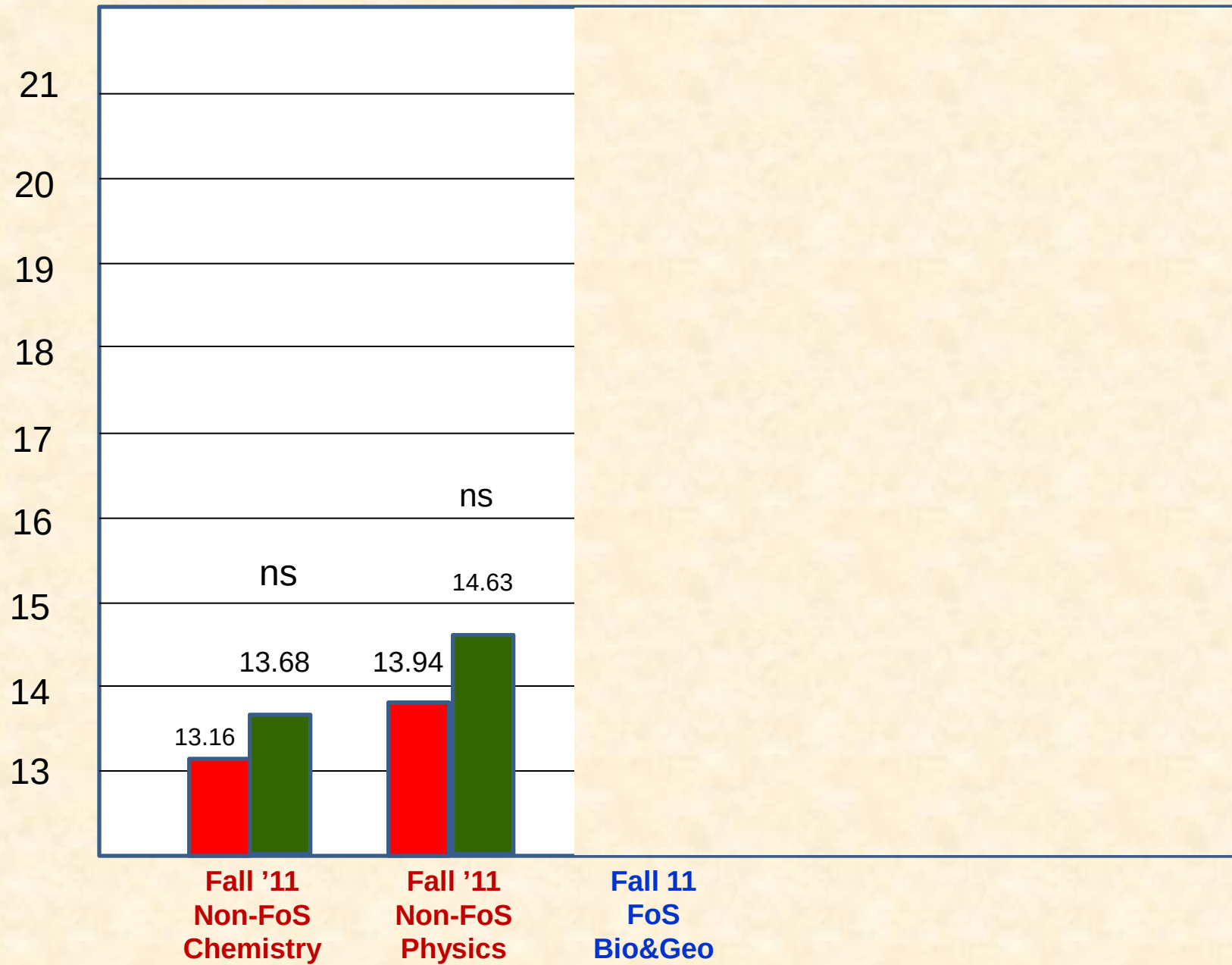
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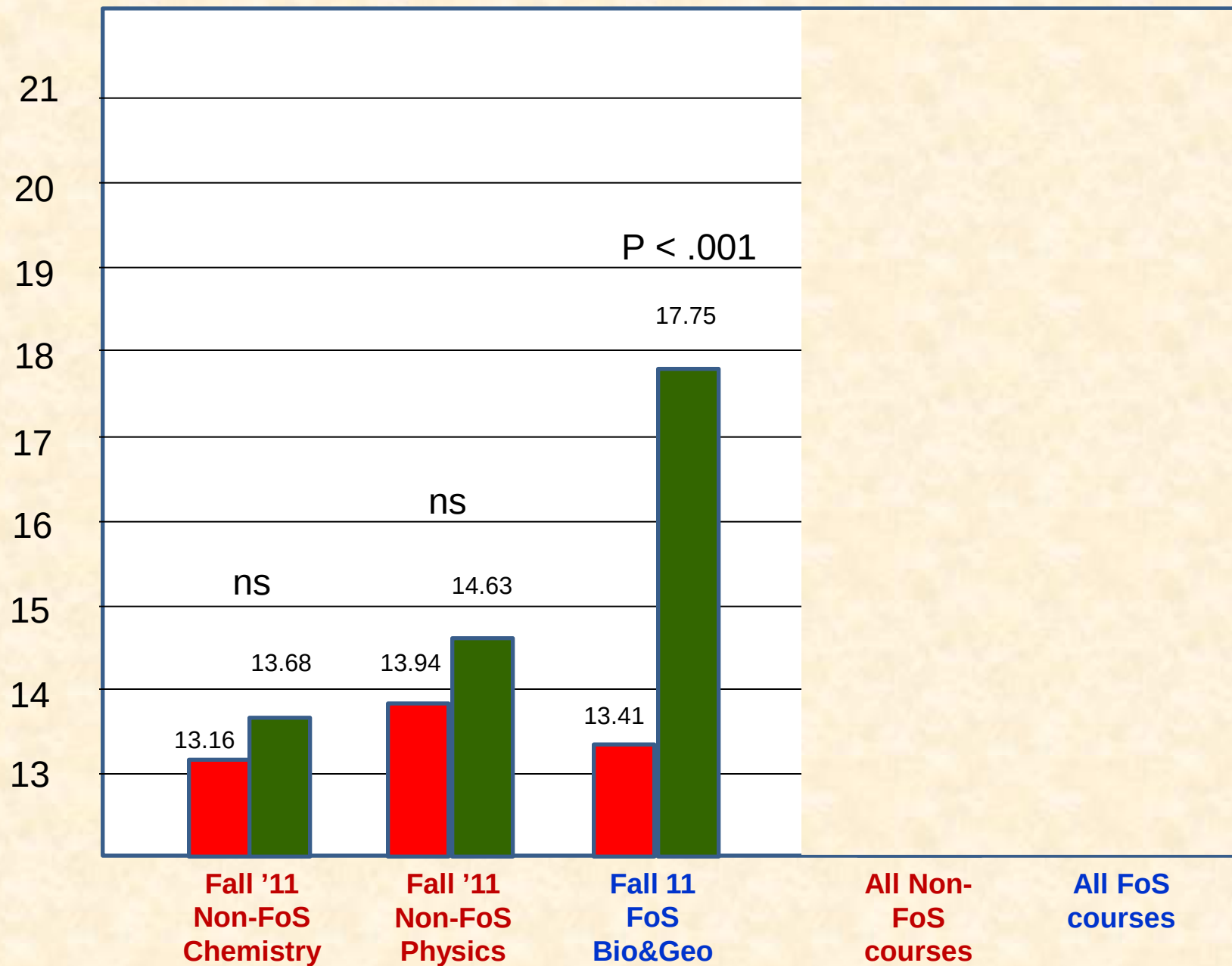


CAT Score

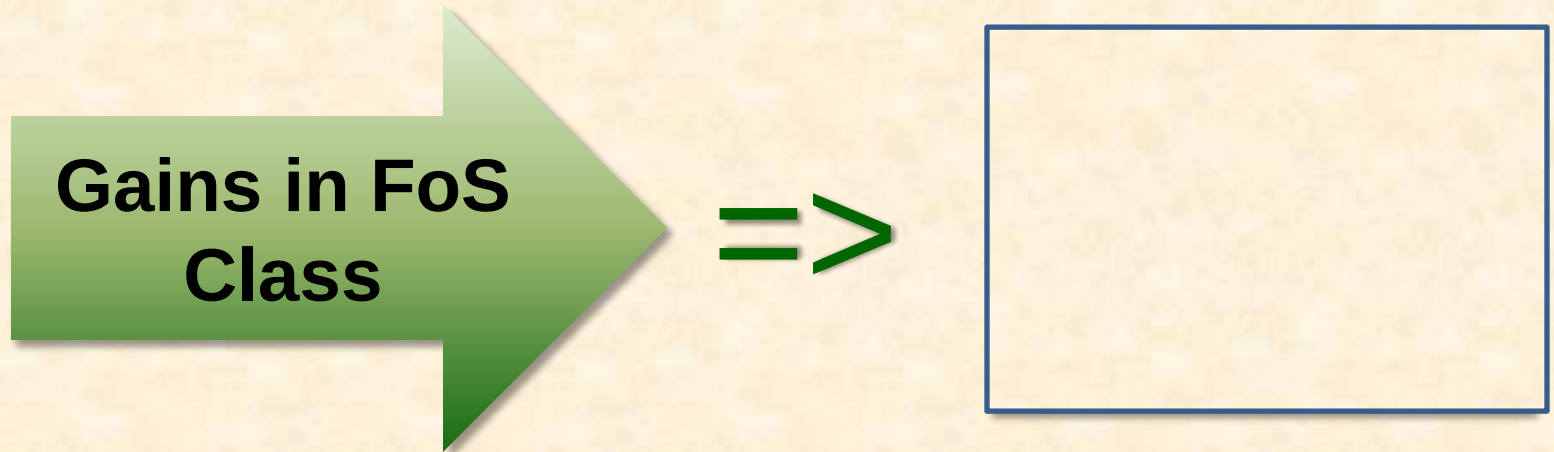




CAT Score

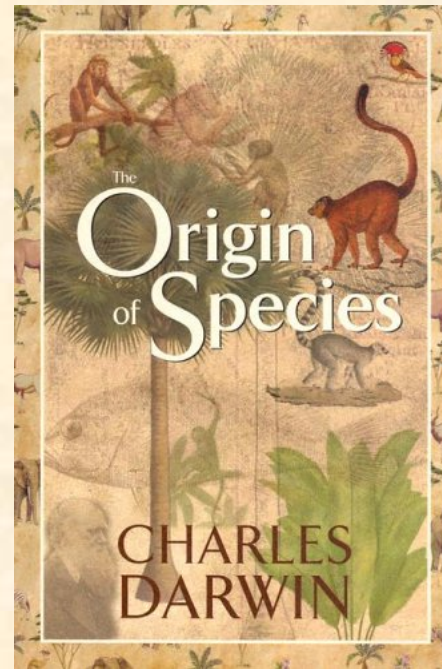


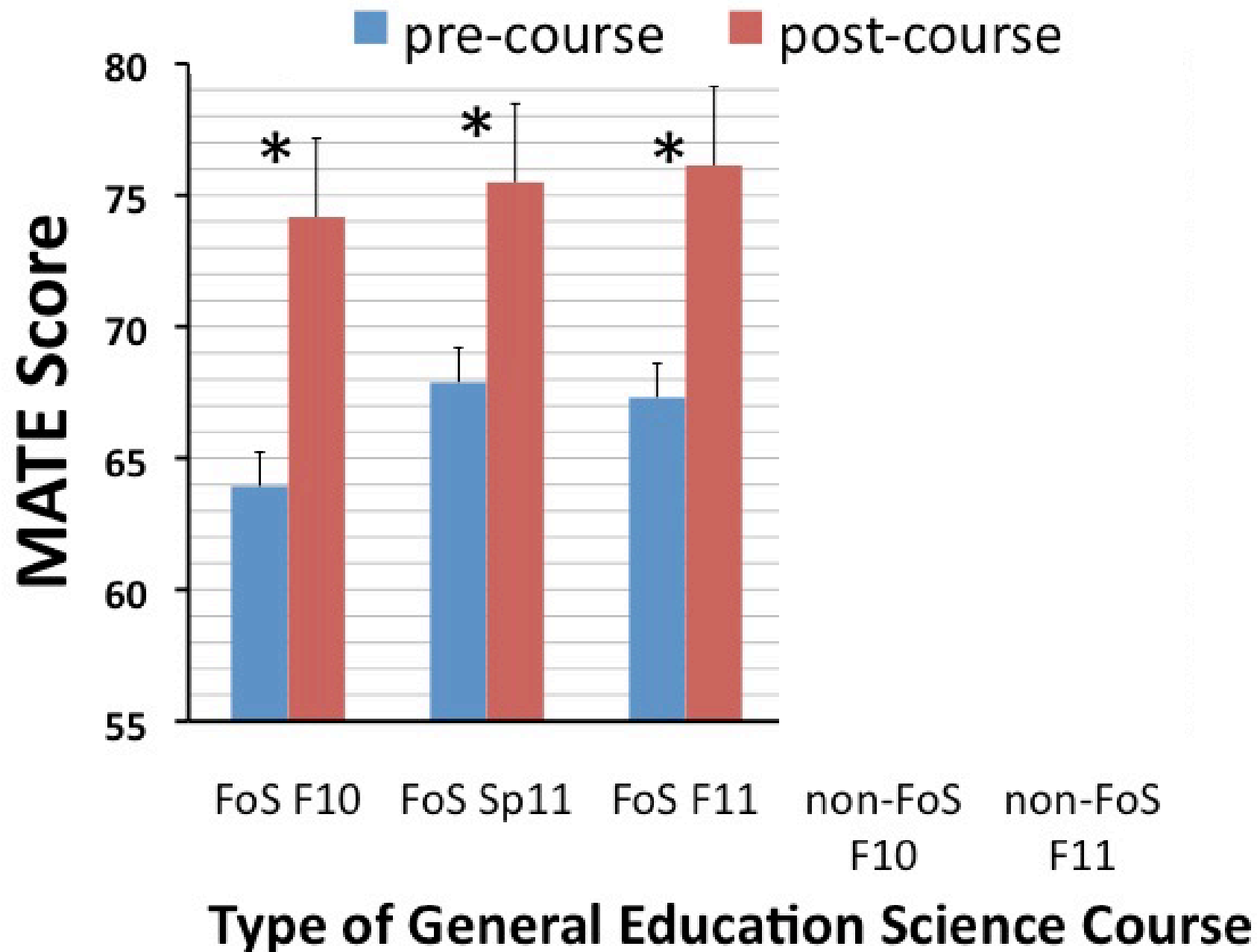
Perspective



Measure of the Acceptance of the Theory of Evolution (MATE)

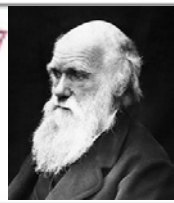
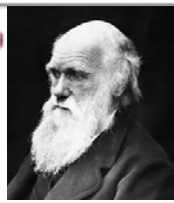
Developed by Michael Rutledge and Kim Sadler





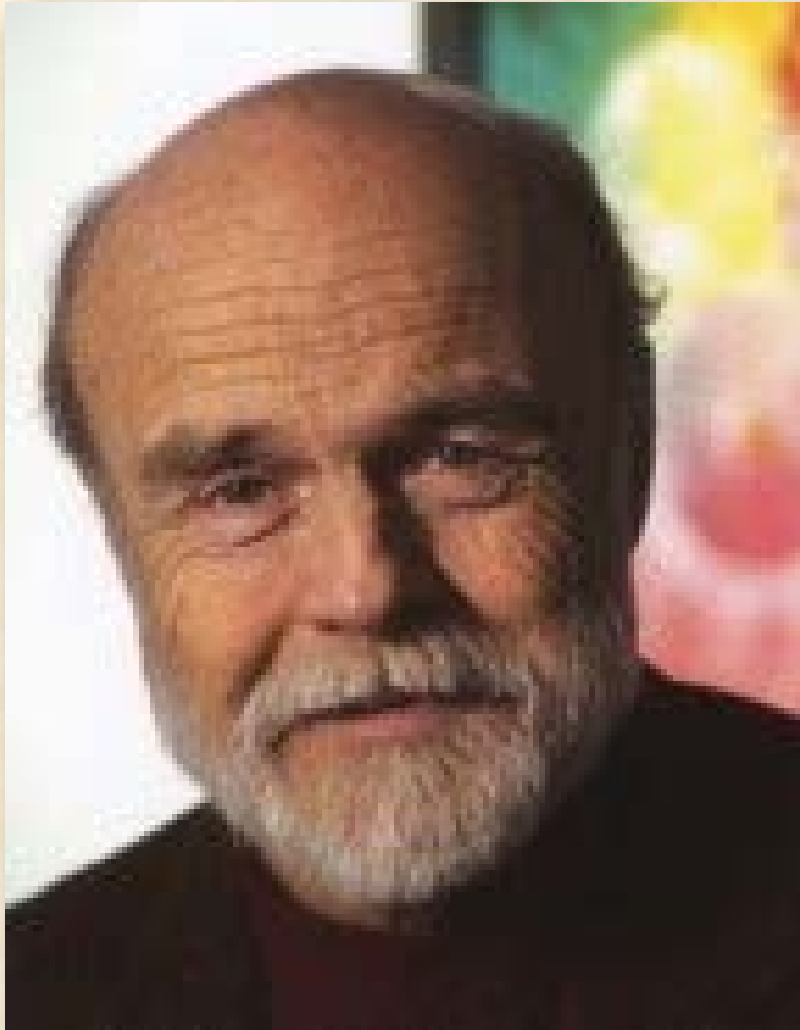


December 2010

sunday	monday	tuesday	wednesday	thursday	friday	saturday
			1 	2	3	4
5	6	7 	8	9 	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24 Christmas Eve	25 Merry Christmas 
26	27	28	29	30	31 New Year's Eve	TheTomKatStudio.com



The Crippling Undergraduate Experience



“We never seem to teach students how to solve real-world problems, or analyze data, or read a newspaper critically, or be a skeptic when they hear people claim to have paranormal powers, or demand sensible answers of politicians...

...What a pity.”

Dr. Kipp Herreid – SUNY Buffalo



Thank you



Slides to address anticipated
questions follow.



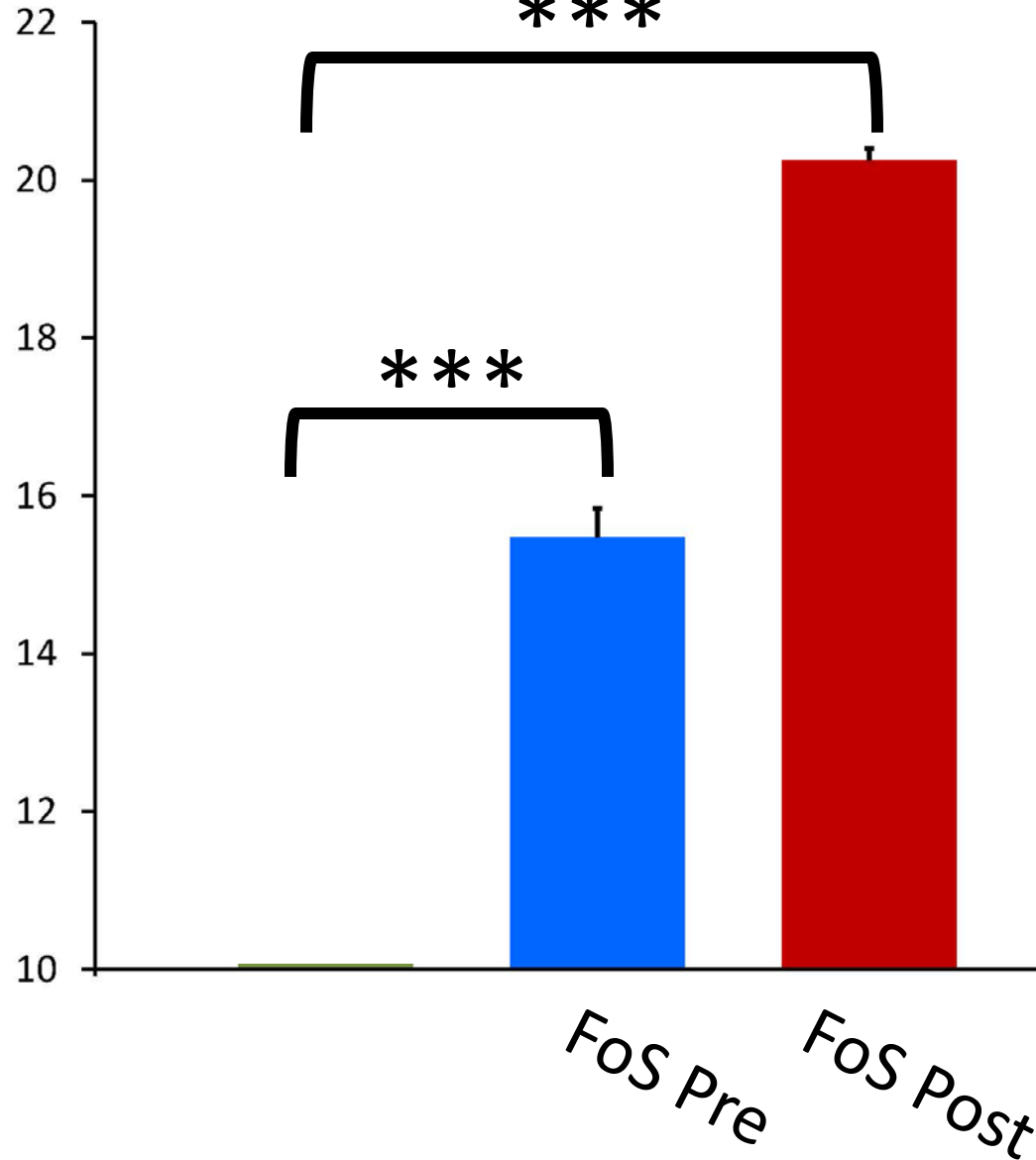
After taking your class this semester and having my critical thinking skills enhanced, I must complain that your class has sucked all of the fun out of being ignorant. I came back to my office after class today, (I work on campus) and my boss was buzzing about this new energy drink called Advocare that she had recommended to her by her friend (who happens to sell the drink). My boss was going on and on about how it is all natural, it's endorsed by a NFL star (Drew Brees), and how hundreds of people have reported a boost in their mental functions and overall health. As I was listening to her, I kept thinking that if I had not taken that stupid science class, I too could be lost in the euphoria of ignorant bliss. Instead, I found myself perusing the website, chuckling at all of the grand statements and lucrative "money-making opportunities" that are available. Instead of being impressed by the drinks capabilities, I was looking for the FDA disclaimer. Instead of being amazed that the drink was all natural, I was reading the ingredients trying to pronounce half of them. Instead of wondering how the drink could help me, I kept thinking of ways that it might hurt me. Needless to say, your class has definitely ruined any joy to be had in the absent-minded following of other people.

I just thought I'd share with you how your class is ruining the American dream of so many honest companies. See you in class."



Lower Division

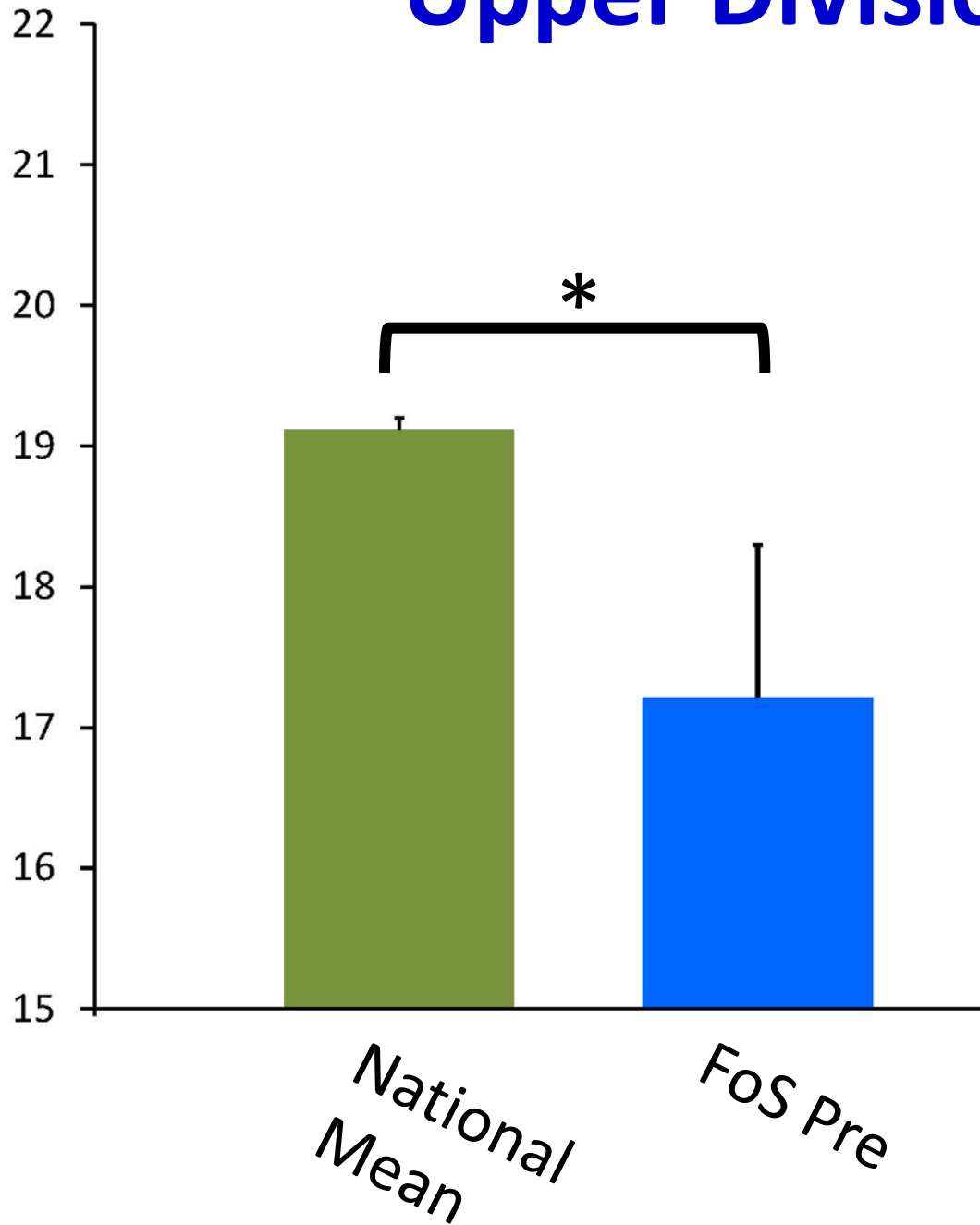
CAT Scores





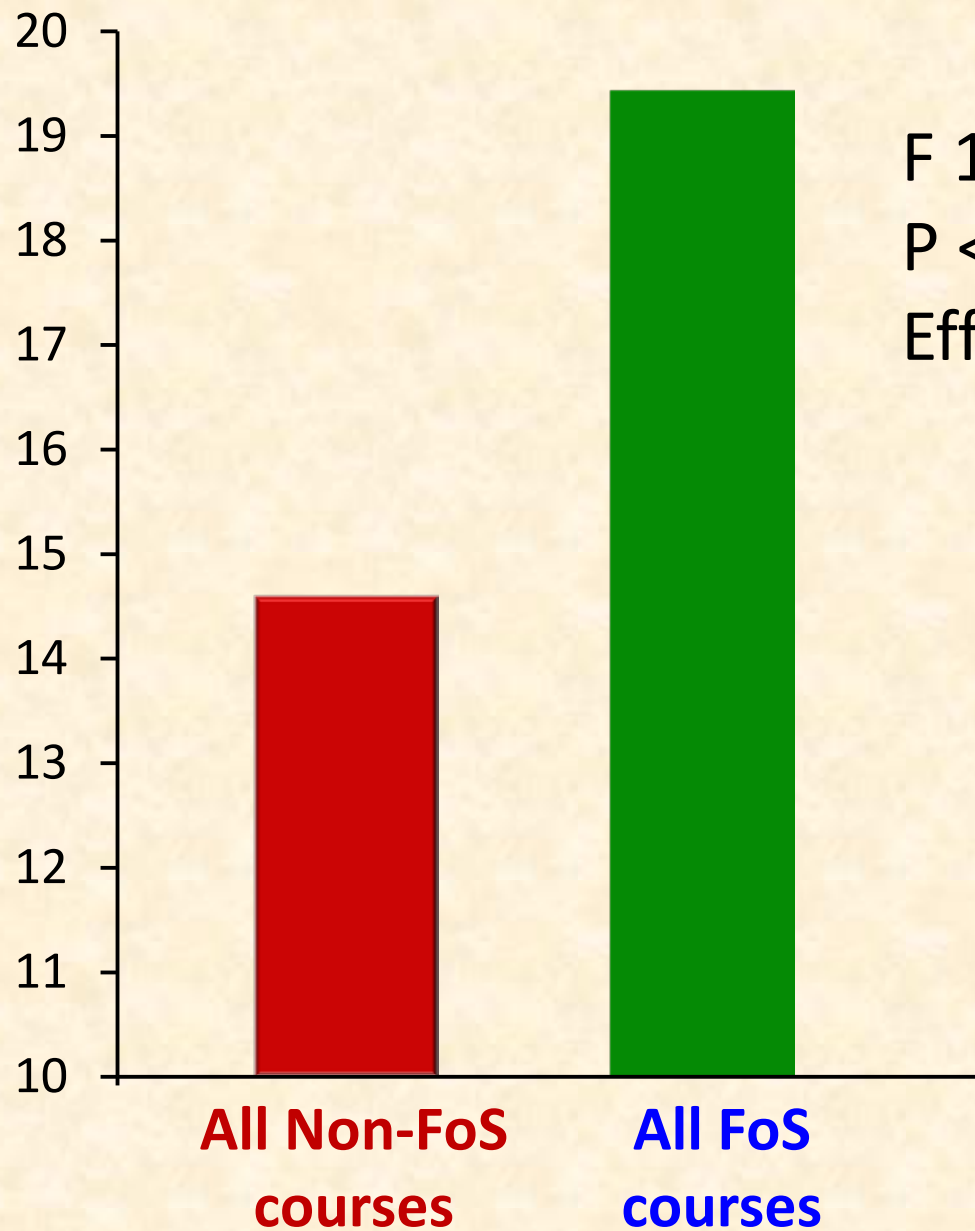
Upper Division

CAT Scores





Adjusted CAT Scores



$F_{1, 173} = 28.9$

$P < 0.001$

Effect Size = 0.90



The American Biology Teacher

69: 332-335, 2007.

Reliability of the Measure of Acceptance of the
Theory of Evolution (MATE) Instrument with University Students

MICHAEL L. RUTLEDGE

KIM C. SADLER

Very High Acceptance: 89-100

High Acceptance: 77-88

Moderate Acceptance: 65-76

Low Acceptance: 53-64

Very Low Acceptance: 20-52