Science Literacy Requires Statistical Literacy

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www.StatLit.org/pdf/2009SchieldSencer6up.pdf

SENCER Goals

SENCER: *Science Engagement for New Civic Engagements and Responsibilities*

1. Interest more students in science, technology, engineering & mathematics (STEM) learning
2. Encourage students to connect STEM learning to their other studies
3. Strengthen students' understanding of science and their capacity for responsible work and citizenship.

Source: www.sencer.net/About/projectoverview.cfm

SENCER: David Burns

SENCER courses are fundamentally designed **to improve intellectual capacity**.

Our thesis is that **improved intellectual capacity** -- originating in and developing within a student's interests and motives and illuminated by real issues of civic importance -- **will also enhance civic capacity**.

Knowledge To Make Our democracy by David Burns

SENCER: Teach science through...

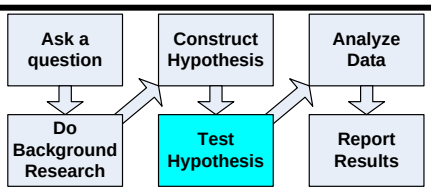
1. a **single** complex, capacious, largely unsolved, civic issue that interests many students

More emphasis on depth: problem immersion and complexity, the production of science.

2. a **number** of science-related unsolved civic issues as they appear in the everyday media.

More emphasis on critical thinking and breadth: evaluating the science – the **scientific method**.

Scientific Literacy Scientific Method



There are two distinct ways of testing hypotheses:

- In **manipulative science**, the scientific method involves experimentation (control of).
- In **observational science**, the scientific method involves only observation (control for).

Science: Manipulative vs. Observational

STEM is more experimental than observational.

1. Technology and engineering are experimental
2. Math is neither
3. Sciences and statistics can be either

Physics: Experimental: Nuclear, solid state
Observational: Astronomy, space physics

Biology: Experimental: Genetics
Observational: Evolutionary Biology

Statistics: Experiments: Randomized assignment
Observational studies: Epidemiology

7 November 2009 Sencer 7

Science Literacy: Observational Studies

Most science-related claims in the media involve observational studies – not controlled experiments.

> "In medical journals, articles involving observational studies (37%) were **50% more prevalent** than those involving randomized trials (25%).
>
> Among related news stories, articles involving observational studies (58%) were **10 times as common** as those involving randomized trials (6%)."
> Schield (2004, IASE)

Stories involving observational studies make news!

7 November 2009 Sencer 8

Science Literacy Means Statistical Literacy

To understand science, students should understand:

- **Mathematical modeling** with homogeneous subjects in classical experiments [Math]
- **Statistical inference** with heterogeneous subjects in randomized experiments and surveys. [Statistics]
- **Epidemiological statistics** in observational studies with heterogeneous subjects.

Statistical literacy includes all three but has a stronger focus on epidemiological studies.

7 November 2009 Sencer 9

Liberal Arts Majors Need Science Literacy

40% of college students are liberal arts majors – students in **non-quantitative majors.**

These liberal arts majors encounter STEM-related issues in the everyday media.

These students need a general-education course to help them analyze science-related claims in the news.

These students need to be scientifically literate. As leaders they are likely to set policies affecting STEM.

7 November 2009 Sencer 10

Statistical Literacy: 10 Question Map

1. **What kind of essay or argument?**
2. **Is causation asserted or implied?**

QL: 3. Does association strongly support causation? 4. Are comparisons, ratios & models appropriate? — QR

QL: 5. Can study design negate influences? 6. Can randomness influence numbers? 7. Can error or bias influence numbers? — Statistics

8. **Can confounders influence numbers?**
9. **Can assembly influence numbers?**
10. **How strong is the argument?**

Schield 2008 National Numeracy Network

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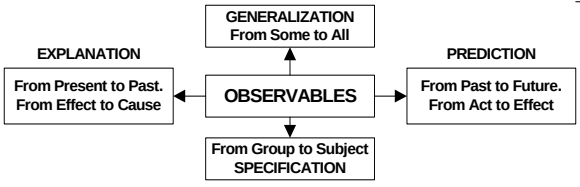
Q1. What Kind of Argument?

Is there a disputable claim that requires an argument or is this just a presentation of facts?

If there is an argument, what kind of argument is involved?



7 November 2009 Sencer 12

TWO HUNTERS AND A BEAR

Two hunters are being chased by a bear. The first hunter yells to the second, "*It's hopeless! This bear can run faster than we can.*"

The second hunter yells back,
"*No it's not hopeless! I don't have to outrun the bear. I just have to outrun you.*"

Q2. Is Causation Asserted or Implied?

1. 45,000 deaths ***attributable to*** uninsurance (PNHP)
2. 45,000 deaths ***associated with*** lack of insurance (CNN)
3. Uninsured Americans ***have*** 40% ***higher*** death risk (Ivanhoe)
4. Study ***links*** 45,000 US deaths to lack of insurance (Reuters)
5. Lack of insurance ***linked to*** 45,000 deaths (White Coat News)
6. No health coverage ***tied to*** 45,000 deaths… (MSNBC)
7. Study: 45,000 U.S. Deaths ***From*** Lack of Insurance (Money News)
8. One American dies every 12 minutes ***due to*** no… insurance (DR)
9. 45,000 Americans die … ***because*** *of* lack of … insurance (MyDD)
10. Lack of Health Insurance ***Kills*** 45,000 …(Health Insurance Inst.)
11. Lack of Health Insurance ***cause*** 44,789 deaths in US (blog)
12. Lack of insurance ***to blame for*** almost 45,000 deaths (HealthDay)

Q2. Is Causation Asserted or Implied?

US Healthcare: Third Leading Cause of Death

225,000 Americans die each year ***as a result*** *of* their medical treatments:

- 7,000 deaths per year ***due to*** hospital medication errors
- 12,000 deaths per year ***due to*** unnecessary surgery
- 20,000 deaths per year ***due to*** other errors in hospitals
- 80,000 deaths per year ***due to*** infections in hospitals
- 106,000 deaths per year ***due to*** negative effects of drugs

Source: www.StatLitBlog.org
Reference: Starfield, B. (2000, July 26). Is US health really the best in the world? Journal of the American Medical Association, 284(4), 483-485.

Q6. Can Randomness Influence the Numbers?

Consider flipping a set of 10 fair coins. [2^{10} = 1,024]

1. **What is the chance of the next set having 10 heads? Pick the closest answer.**
   a. 50% b. 10% c. 1% [d. 0.1%] e. 0.01%

Consider flipping 1,024 sets of 10 fair coins each.

2 **What is the chance of finding any of these sets that has 10 heads? Pick the closest answer.**
   a. 90% [b. 50%] c. 10% d. 1% e. 0.1%

Q6. Can Randomness Influence the Numbers?

Assume that the test for statistical significance is no overlap of the associated 95% confidence intervals.

1,000 surveyed: 95% margin of error is ± 3 points
Assume: 50% are male and 20% are black.
Data: *Percentage of the group indicated who said Yes.*

Q. Are these differences statistically significant?

1. Men 55%, Women 50% No
2. Men 57%, Women 50% No: ME=3pt*Sqrt(2)
3. Blacks: men 66%, women 50% No: 3pt*sqrt(10)
4. Men 3%, Women 1%. Yes; ME=3pt*sqrt(2/50)

Q7. Can Error or Bias Influence the Numbers?

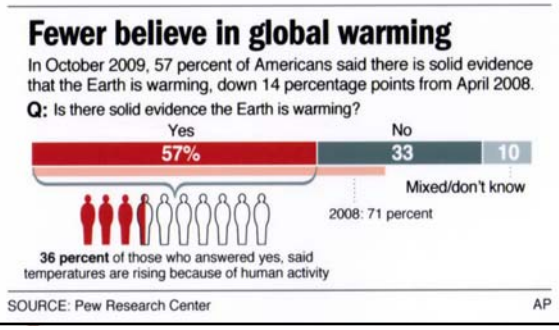
British experts studied more than 17,000 children born in 1970 for about four decades.

Of the children who ate candies or chocolates daily at age 10, **69% were later arrested for a violent offense by the age of 34**.

This 69% statistic is an error; it is false.
It involves a confusion of the inverse. It should be:
"**69% of violent criminals ate candy as kids**"

Source: AP story. See www.StatLitBlog.org

Q7. Can Error or Bias Influence the Numbers?



7 November 2009 Sencer 19

AP Chart was Based on this 100% Table

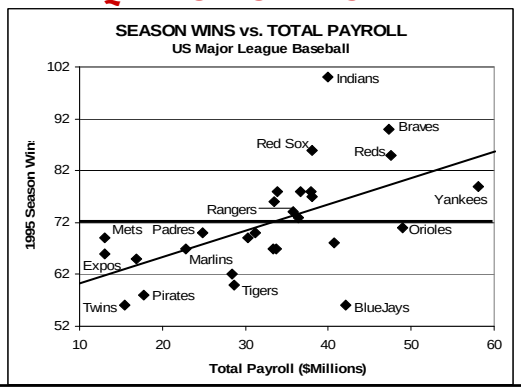
Is there solid evidence of global warming?	
YES	57
Because of human activity	36
Because of natural patterns	16
Don't know	5
NO	33
DON'T KNOW	10
ALL	100

1. 36% of respondents said temperatures are rising because of human activity.
2. 36% of those who answered Yes, said temperatures are rising because of human activity.

AP chart is based on #2: an error. AP retracted the chart

7 November 2009 Sencer 20

Q8. Confounders?



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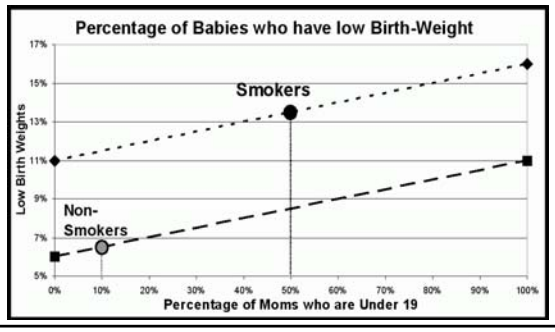
Q8. Weighted Averages: Graphical View



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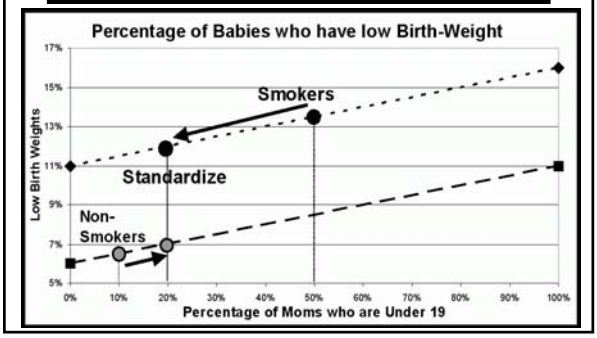
Q8. "Take into Account" by Standardizing



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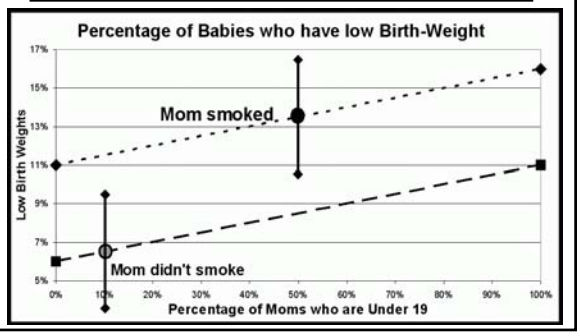
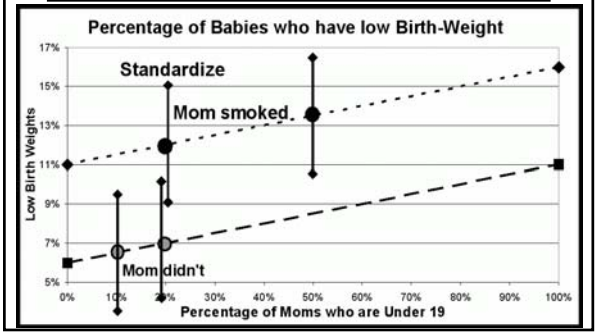
Statistically Significant Before Standardizing



7 November 2009 Sencer 24

Statistically In-significant After Standardizing



Q9. Can Assembly Influence the Numbers?

Half of US kids will get food stamps, study says

Associated Press | Buzz up! 138 votes | Send | Share | Print

By LINDSEY TANNER, AP Medical Writer – Mon Nov 2, 9:32 pm ET

SOURCE: 11/2/2009 Yahoo.com

Nearly half of all U.S. children and 90% of black youngsters will be on *at some point during childhood*

about 49% of all children were on food stamps at some point *by the age of 20*, the analysis found. That includes 90% of black children and 37% of whites.

Q9. Can Definition Influence the Numbers?

- 30% of children in grades 6 - 10 have moderate or frequent involvement in bullying.

Bullying can take three forms:

- **physical** (hitting, kicking, spitting, pushing, taking personal belongings);
- **verbal** (taunting, malicious teasing, name calling, making threats); and
- **psychological** (spreading rumors, manipulating social relationships, or engaging in social exclusion, extortion or intimidation). (Joel Best, 2002)

Q9. Can Presentation Influence the Numbers?

At its closest, Earth is 3 million miles closer to the sun than at its furthest.

The earth is 3% closer to the sun at its closest.

The earth-sun distance varies by 1.5% from the mean.

1. Federal Reserve **doubles** interest rates
2. Federal Reserve increases interest rates by **100%**
3. Federal Reserve increases interest rates by **1 point**

Q. Could all three of these be true simultaneously?

Answer: Yes by increasing rates from 1% to 2%.

Conclusion

To make intelligent decisions in a data-driven democracy, *citizens must understand the different types of science they encounter in everyday life.*

Students must be given a wide variety of science-related news stories. They must learn how to

- analyze the arguments,
- *understand the influences on the numbers*, and
- reach a reasoned, nuanced conclusion.

Once this skill is acquired, it can be used on a daily basis throughout their life.

References: Books

Lynn Steen: *Why Numbers Count: Quantitative Literacy for Tomorrow's America* (1997), *Mathematics & Democracy: The Case for Quantitative Literacy* (2001) and *Achieving Quantitative Literacy* (2004).

Joel Best: *Damned Lies and Statistics* (2001), *More Damned Lies and Statistics* (2004) and *Stat-Spotting* (2008).

Jane Miller: *The Chicago Guide to Writing About Numbers* (2004) and *The Chicago Guide to Writing on Multivariate Analysis* (2006).

Gary Klass (2008): *Just Plain Data Analysis*.

See books at www.StatLit.org

References: Papers

Overview: *Analyzing Numbers in the News*
www.statlit.org/pdf/2008SchieldNNN.pdf

Distinguishing Association from Causation in Headlines
www.statlit.org/pdf/2009SchieldRaymondASA.pdf

- **Context:** *Presenting Confounding Graphically*
  www.statlit.org/pdf/2006SchieldSTATS.pdf
- **Assembly:** *Teaching the Social Construction of Statistics*
  www.statlit.org/pdf/2007SchieldMSS.pdf
- **Randomness**: *Statistical Literacy and Chance*.
  www.StatLit.org/pdf/2004SchieldASA.pdf