Quantitative Literacy: An Imperative for America

Bernie Madison
University of Arkansas
Computers have made data easy to gather and analyze. Data and numbers occur in many areas of daily life.

<table>
<thead>
<tr>
<th>Individual Decisions</th>
<th>Decisions as Citizens</th>
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<tbody>
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<td>• Health care</td>
<td>• Voting and polling</td>
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<td>• Retirement plans</td>
<td>• Laws – regulation &amp; de-regulation</td>
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<td>• Rents and mortgages</td>
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<td>• Investing</td>
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<td>• Risk of terrorism</td>
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<td>• Sports results</td>
<td>• Election procedures</td>
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</tbody>
</table>
Quantification of US Society

- 1250 – 1550: Qualitas to Quantitas
- 1550 – 2009: Risk
- 1700 – 1850: Calculating People
- 1850 – 2009: Deregulation & Re-regulation
- 1950 – 2009: Complete Market
- 1970 – 2009: Computerization
Quantification of Western Society
The Measure of Reality by Alfred W. Crosby (1997)

1250 - 1600
Venerable Model to the New Model

St. Thomas Aquinas (1225 or 1227 – 1274).

to

Galileo (1564 – 1642)

Qualities to Quantities
Why did humanity wait the many thousands of years leading up to the Renaissance before breaking down the barriers that stood in the way of measuring and controlling risk? ... It was a game of chance that inspired Pascal and Fermat’s revolutionary breakthrough into the laws of probability, not some profound question about the nature of capitalism or visions of the future.
The ultimate extension of a seemingly trivial pursuit

In 1953, economic Nobelist Kenneth Arrow used tools of quantification to articulate a world in which every potential outcome would have a predictable price tag. This idealized "complete market" is a direct albeit distant descendent of the nobleman's unfinished games of chance.
Arithmetic, I presume, comes by instinct among this guessing, reckoning, expecting, and calculating people.

Thomas Hamilton, 1830

Unceasingly they weighed risks, computed advantages, and gauged the utility of any particular course of action ... Their minds were accustomed to definite calculations.

Alexis de Tocqueville, 1830
Fueling US demands for QL

- Apportionment
- Census
- Competitive & comparative
- Individual freedoms
- Demands of a democracy
- Free markets
- Agile economy
- Minimal economic safety nets
- Deregulation
- Privatization
Mismatch between a quantified society and an innumerate population...

- Matthew Arnold, English poet and cultural critic, 1884 lament about America’s more is better culture.
- As Bob Orrill put this in his Wingspread essay on QL, “In plain speech, Arnold means that all this talk of abundance is tiresome stuff.”
- Has qualitas to quantitas gone too far?
- If not, can we educate our citizens so that they can understand these quantifications?
From a letter to the editor,
Arkansas Democrat Gazette 18 March 2005

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...

“The Democrats tell us that we cannot afford to allow younger workers to put 2 percent of their payroll taxes into private accounts because that would result in a $2 trillion shortfall of the Social Security fund that would wreck the system.

Does anyone actually believe that? If 2 percent equals $2 trillion, then the other 98 percent must equal $98 trillion. And let’s see, since Social Security taxes are about 20 percent of a worker’s tax burden, then we can assume that 100 percent of the federal taxes collected each year must be around $500 trillion. Wow!”
...

...
These are different

- 40% to 60% is an increase of 20%
- 40% to 60% is an increase of 50%
- Percentage of women in the labor force with a child under 1 year of age
- Percentage of mothers of children under 1 year of age who are in the labor force
Literacy has two very different meanings and this difference creates problems for QL education.

1) Literacy is often viewed as minimum competency as in “He is barely literate.”

2) Literacy is sometimes viewed as a high level of learning as in literati, or the educated class or intelligentsia.
Two Kinds of Literacy

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- **Inert** - Level of verbal and numerate skills required to comprehend instructions, perform routine procedures, and complete tasks in a routine manner.

- **Liberating** - Command of both the enabling skills needed to search out information and power of mind necessary to critique it, reflect upon it, and apply it in making decisions.

QL or Numeracy

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- QL or numeracy is the power and habit of mind to search out quantitative information, critique it, reflect upon it, and apply it in their public, personal and professional lives. (NNN in Crimen’s words)

- QL is a cultural field where language and quantitative constructs merge and are no longer one or the other. (Robert Orrill)

Evolution of QL (AKA Numeracy)

- **1959-1982: Formative phase**
  - Simple arithmetic skills normally acquired in childhood

- **1982- late 1990s: Mathematical phase**
  - Ability to use mathematics in everyday life and to understand and appreciate information presented in mathematical terms

- **1990s to present: Integrative phase**
  - The power and habit of mind to search out quantitative information, critique it, reflect upon it, and apply it in public, personal and professional lives (NNN vision)
  - Cultural field where language and quantitative constructs merge and are no longer one or the other (Bob Orrill)

Mathematics vs. QL

Mathematics
- Power in abstraction
- Power in generality
- Some context dependency
- Society independent
- Apolitical
- Methods & algorithms
- Well-defined problems
- Approximation
- Heavily disciplinary
- Problem solutions
- Few opportunities to practice
- Predictable

QL
- Real, metamorphic contexts
- Specific, particular
- Heavy context dependency
- Society dependent
- Political
- Ad hoc methods
- Ill-defined problems
- Estimation is critical
- Interdisciplinary
- Problem descriptions
- Many practice opportunities
- Unpredictable
Relatives of QL

- Mathematical literacy
- Numeracy
- Symbol literacy
- Document literacy
- Financial literacy
- Statistical literacy
- Quantitative reasoning
- Critical reasoning
- Analytical reasoning
- Scientific literacy
- Symbol literacy
- Technical literacy
- Ethnomathematics
- Functional mathematics
Has education responded?

• Adapted to society that swims in information?

• Teach reasoning or facts and methods?

• Have synergism across our disciplines?

• Perform or guide?

• Teach our subjects the way they were developed?

• Do students know why they should learn?
Mathematical reasoning

- Numbers and quantities
- Percent and percent change
- Linear and exponential growth
- Graphical interpretation and production
- Measurement and indices
- Counting, probability, odds, and risk
Learning Goals

• Recognize the importance of units
• Recognize uses mis-uses of numbers and quantities
• Interpret large (or small) quantities in personally meaningful terms (Units)
• Compute on the fly - estimate and approximate
• Compare quantities
More/less than

How much more/less than

Ratios:

Percent

Percent more/less

Times

Times more/less ???

Comparing quantities should make sense ...
Canonical problem situation

- Have confidence to take up the challenge.

- Glean out the relevant information.

- Estimate to see if assertions are reasonable.

- Model with mathematics or statistics.

- Do the mathematics or statistics

- Reflect on the results.
We can skip the oath... numbers don't lie.
We are invited to compare a wealthy ruler with the poverty of the ruled...
Context matters!

Percentage of black students who attend schools that are more than 50% white: 89%

Percentage of white students who attend schools that are more than 50% minority: 72%

Source: 2002 study by the National Center for Education Statistics.
### GOP Disputes

**Vying To Set Deficit Record Straight**

The $304 trillion budget deficit projected by the Bush administration for 2003 would be the largest ever. But Republicans are quick to point out the deficit would not be a record when adjusted for inflation or represented as a percentage of the gross domestic product.

#### Federal Budget Surpluses And Deficits

**In Real Dollars**

<table>
<thead>
<tr>
<th>$400 billion</th>
<th>$304 billion</th>
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<tbody>
<tr>
<td>-200</td>
<td>-200</td>
</tr>
<tr>
<td>-400</td>
<td>-400</td>
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</table>

**In 1996 Dollars**

<table>
<thead>
<tr>
<th>$367 billion</th>
<th>$304 billion</th>
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<tbody>
<tr>
<td>-200</td>
<td>-200</td>
</tr>
<tr>
<td>-400</td>
<td>-400</td>
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</table>

**As Percentages Of GDP**

<table>
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<tr>
<th>4 percent</th>
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<tbody>
<tr>
<td>-4</td>
</tr>
<tr>
<td>-2</td>
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</tbody>
</table>

**SOURCE:** Office of Management and Budget

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### Is the glass half full . . .

Conservatives look at the federal government and see an alarming growth in discretionary spending — spending unrelated to mandatory programs such as Social Security and Medicare:

#### Discretionary spending

<table>
<thead>
<tr>
<th>IN BILLIONS OF DOLLARS</th>
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<tbody>
<tr>
<td>'96</td>
</tr>
<tr>
<td>'97</td>
</tr>
<tr>
<td>'98</td>
</tr>
<tr>
<td>'99</td>
</tr>
<tr>
<td>'00</td>
</tr>
<tr>
<td>'01</td>
</tr>
<tr>
<td>'02</td>
</tr>
<tr>
<td>'03</td>
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</tbody>
</table>

#### Government revenues as a share of GDP

<table>
<thead>
<tr>
<th>PERCENT CHANGE</th>
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<tbody>
<tr>
<td>'96</td>
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<tr>
<td>'97</td>
</tr>
<tr>
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<td>'02</td>
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<td>'03</td>
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</tbody>
</table>

*projected

**SOURCES:** Heritage Foundation, Center on Budget and Policy Priorities
Are these two views compatible?
Can one determine how much the tax cut is?

ON THE OTHER HAND . . .

Two Views of a Tax Cut

Republican
Math: An Even
Cut Across
the Board

Democratic
Math: A Select
Few Get the
Benefits

How much taxes
would fall for
families in each
group

Source: House
Ways and
Means
Committee

Source: Treasury Dept.
Decade After Health Care Crisis, Soaring Costs Bring New Strains

The Costs Of Health Care, And the Shifts In Coverage

From 1960 to 2000, the United States population increased 57%. Over the same period, national health care spending increased 909%.

- 1960: $120 billion
- 1970: $251 billion
- 1980: $431 billion
- 1990: $805 billion
- 2000: $1,214 billion
- 2010 (projected): $1,870 billion

National health care spending
Figures adjusted for inflation in 1996 dollars
Candidates running in the presidential campaign are increasingly drawing contributions from Americans living overseas.

<table>
<thead>
<tr>
<th></th>
<th>Britain</th>
<th>China</th>
<th>France</th>
<th>Japan</th>
<th>Canada</th>
<th>Switzerland</th>
<th>U.S. military bases abroad</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barack Obama</td>
<td>125</td>
<td>25</td>
<td>22</td>
<td>17</td>
<td>6</td>
<td>17</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>Rudolph W. Giuliani</td>
<td>84</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Hillary Rodham Clinton</td>
<td>13</td>
<td>0.25</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>Mitt Romney</td>
<td>30</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>John Edwards</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>0.5</td>
<td>6</td>
<td>3</td>
<td>8</td>
<td>4</td>
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<tr>
<td>John McCain</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>2</td>
</tr>
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</table>

Source: Federal Election Commission
Directions

The chart shows how companies in a category performed versus the S&P 600 over the last week and year.

Circles are sized according to their current market capitalization in the category index.

For an interactive chart: nytimes.com/business
**How to read the chart**

The chart shows how companies in a category performed versus the S.& P. 500 over the last week and year.

- Circles are sized according to their current market capitalization in the category index.
Who says USA Today is written at the 6th grade level?

How to use this chart

1. Weekly change (W)
   - A green pole means the industry group rose for the week – the taller the pole, the better the performance.
   - Red poles mean the group fell for the week.

2. Monthly change (M)
   - The left-hand scale shows how a group fared the past 30 days. The closer the pole is to the top of the chart, the better.

3. Quarterly (3-month) change (Q)
   - Use the bottom scale to see how a group did the past 3 months. Poles closest to the chart’s right edge have fared best.

Questions about the stock market?
Ask USA TODAY’s Matt Krantz today at 1 p.m. ET at talk.usatoday.com.

By Jen Serpent and Robert W. Almonte, USA TODAY

USA Today July 6, 2004
Compactification of a bar graph...
1 - highly unacceptable
2 - unacceptable
3 - acceptable
4 - highly acceptable

**FIGURE 1.4** The Interaction of Sex of Respondent and Sex of Transgressor on the Acceptance of Sexual Betrayal
LOOK AT THIS! MY HOMEWORK PILE IS 21 INCHES HIGH! THAT'S 7 INCHES MORE THAN LAST YEAR - A 50% INCREASE!

WHY DO 100% OF MY TEACHERS GIVE 100% HOMEWORK 100% OF THE TIME? 5 SUBJECTS, AN HOUR EACH = 5 HOURS OF HOMEWORK!

IF I COULD ELIMINATE JUST ONE SUBJECT, I'D HAVE AN EXTRA HOUR

WHAT SUBJECT WOULD YOU ELIMINATE?

I DUNNO. PROBABLY MATH. WHEN DO I EVER USE THAT?
Where The Renters Are

More folks rent in Washington County than the state or national average.

32% Arkansas
43% Washington County
33% United States
28% Benton County

Source: U.S. Census Bureau

MICHELLE OBANA THE MORNING NEWS
How Prison Works

Recidivism Rate of Prisoners Released in 1994

- **All Released Prisoners**: 67.5%
- **Violent Offenses**: 61.7%
- **Property Offenses**: 73.8%
- **Drug Offenses**: 66.7%
- **Public-Order Offenses**: 62.2%
- **Other Offenses**: 64.7%

Based on a study tracking 272,111 prisoners in 15 states.

Never mind!

Hoover’s claim (including the “56% more” that resembles 100 percent more) is undermined by the message revealed when you follow the asterisk. It says: “The Hoover Cleaning Performance System is for comparing the relative progressive performance of Hoover uprights only and not for comparison with any other brands.”
Which high is higher?
Is this global warming, or are we just less sensitive to the cold?
The surge and the draw down
At the end of January, the United States had about 132,000 troops in Iraq. By next July, Gen. David Petraeus said, the extra 30,000 troops sent as part of President Bush’s revised strategy would be withdrawn. The combat portion of that force includes five Army brigades, two Marine infantry battalions and the 13th Marine Expeditionary Unit. The buildup also included 8,000 support troops.

Notes: Increase past 30,000 is temporary as units leaving and arriving overlap. Also, the actual withdrawal would be more gradual than represented here.

Sources: Washington Post; Associated Press
Mathematical Proficiency from *Adding It Up*

- **conceptual understanding** - comprehension of mathematical concepts, operations and relations
- **procedural fluency** - skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
- **strategic competence** - ability to formulate, represent, and solve mathematical problems
- **adaptive reasoning** - capacity for logical thought, reflection, explanation, and justification
- **productive disposition** - habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

Probably most important one for QL