Quantitative Literacy Goals: Are We Making Progress?

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I am very pleased to have the opportunity to address the question of whether we are making progress toward our goals for quantitative literacy. Let me answer by paraphrasing a comment made by the late Congressman George Brown of California. He was the best friend and most constructive critic of science in the U.S. Congress and we all miss his wisdom. He would say that if you don't know where you're headed, any route will be the right one.

What has this to do with making progress toward our quantitative literacy goals? I would answer, everything. We do not really know if we are making progress. We do not have genuine benchmarks for what constitutes quantitative literacy.

I do not mean to be coy. Quantitative literacy for college- and graduate school-bound students is necessarily going to be more important than for those who stop with a high school diploma, followed by technical certification, in competing for the growing number of highly technical jobs generated by society today.

As our society is driven increasingly by science and technology, the need to establish levels of quantitative literacy becomes ever more important. We must remember that levels are not ceilings, but floors. If no child is to be left behind, he or she should have the best opportunity to reach as high as possible.

But, we must be pragmatic. Not everyone will be in the top level, nor can be. We live in, and are enriched by, our highly heterogeneous population—an enviable strength of our nation. Several studies, such as the National Adult Literacy Survey and the Third International Mathematics and Science Study, have revealed that we need to be both active and vigilant. A significant number of our citizens lack basic knowledge in many areas of science and mathematics.

Lack of understanding of basic science has even become the fodder for jokes on "The Tonight Show." Jay Leno can generate humor just by asking people on the street simple questions about science or mathematics. Common knowledge is not always as common as we would hope; the extremes can be rather surprising. If instead of being about science the questions were about Michael Jordan's field goal percentage, or statistics from this year's World Series, or how many ounces there are in a Big Gulp, would the results be different? If any of us had been approached on the street by Jay Leno and asked questions about economics, or civic planning, or even nutrition, how would we have fared?

Literacy is a complicated issue. Despite indicators showing that a lot of work needs to be done, we should not be discouraged. Foremost, educators should be recognized for their efforts, not frustrated with limited resources or branded by public perceptions of their shortcomings.

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Our efforts should be positive. Our highest priority should be to encourage a favorable impression of mathematics, not just through efforts in the schools but also in the everyday lives of all Americans. We need to accomplish two goals.

First, we need to bring all Americans to a level of literacy appropriate to their daily activities and their future aspirations. Second, we need to communicate that mathematics is everywhere, that in addition to practical value it can be exciting and even artistic and aesthetic.

The need for quantitative literacy can vary from understanding the rise and fall of the stock market, to balancing a checkbook, to understanding risk. The latter, risk, is a greater concern in recent months. In his book *Against the Gods: The Remarkable Story of Risk,* economic consultant Peter L. Bernstein relates the following story, encapsulating how risk perception can change in stressful situations:

> One winter night during one of the many German air raids on Moscow in World War II, a distinguished Soviet professor of statistics showed up in his local air raid shelter. He had never appeared there before. "There are seven million people in Moscow," he used to say. "Why should I expect [the German bombs] to hit me?" His friends were astonished to see him and asked what had happened to change his mind. "Look," he explained, "there are seven million people in Moscow and one elephant. Last night they got the elephant." (Bernstein 1996, 116)

As the statistician knew, the probability was still low that he would be a target. Yet, low probability was shallow comfort when the outcome could be death. That particular case brought home the fact that even low probability events happen. When we have little direct control over our fate, a firm understanding of probability can alleviate some of the stress.

As the recent anthrax crisis demonstrated, the public and the authorities would have benefited from a better understanding of such concepts as diffusion of aerosols, epidemiology, and germ theory. The nation would have benefited from knowing the very small probability of a tainted letter arriving at anyone's doorstep, or from understanding how infection differs from exposure. Fundamentally, the public would have benefited from a solid mix of scientific and quantitative literacy.

But what level of quantitative knowledge does each American need to function effectively under daily conditions? How much interest in quantitative knowledge should we realistically expect when no crisis is imminent?

Quantitative literacy, just like English literacy or historical literacy, exists in degrees. If you asked historians what information they would ideally want each American to know, they probably would suggest topics critical to our nation's future but not relevant to our daily lives: the Whiskey Rebellion,[1] Seward's Folly,[2] the Jethro Tull[3] of circa 1701 Britain, as opposed to the Jethro Tull[4] of circa 1971. And historians would want us to know more than the necessary facts; they would say that we should know the historical context and the insight the events shed on the nature of human experience.

When asked what information all Americans *must* know, however, historians would probably bring up subjects such as the Constitutional Convention, or Standard Oil, or *Brown v. Board of Education*—issues that are critical to understanding our present society.

Ours would be a more effective, and perhaps more rational, society if all Americans felt the same fascination for the magic of numbers and the elegance of graphic representations that we, as scientists, do. The public, however, is most concerned with issues affecting them daily, and it is the role of quantitative literacy in our daily lives that must be understood. People are comfortable using numbers in daily activities with which they are familiar—shopping, tracking sports statistics, even day-trading.

In schools, we likely can make daily quantitative activities a bridge to higher levels of understanding. More may choose to elevate their literacy, coming to appreciate what that master of quantitative representation, Edward Tufte, called "the clear portrayal of complexity. Not the complication of the simple; rather . . . the revelation of the complex" (Tufte 1983, epilogue).

So what are our standards for literacy in the United States? In 1988, Congress passed the Adult Education Amendments, mandating the U.S. Department of Education to define literacy and measure the extent of literacy among Americans. The definition eventually accepted by Congress characterizes literacy as "an individual's ability to read, write, and speak in English and compute and solve problems at levels of proficiency necessary to function on the job and in society, to achieve one's goals, and to develop one's knowledge and potential."

The Department of Education's first National Adult Literacy Survey was conducted in 1992. It questioned 26,000 Americans ages 16 and older and measured not just quantitative literacy but also prose and document literacy. As we would expect, individuals with less formal education dominated the lower levels. Of great concern, minorities tended to have less formal education and were overrepresented in the lower literacy levels.

Similar trends were observed in the Third International Mathematics and Science Study—Repeat (TIMSS-R) and the recent National Assessment of Educational Progress reports on mathematics and science. In the TIMSS-R evaluation of the mathematics and science skills of eighth graders from around the world, the United States ranked only about average in both mathematics and science; however, students from disadvantaged minorities ranked below average. Students from higher-income school districts ranked on a par with their highest-ranking international counterparts.

Americans who are given access to excellent resources are, for the most part, receiving an excellent education. In our country, literacy is most frequently linked to socioeconomic factors. Not all of U.S. education is in crisis, but the unequal distribution of resources is a cause for great concern. For several years, the National Science Foundation (NSF) has funded systemic reform initiatives in both urban and rural school districts to improve overall science and mathematics education. The results have been very encouraging.

Comprehensive and constructive assistance always works better than berating education systems as a whole. Teachers are not the root cause of all problems. We must recognize that there *are* great educators out there for our young people. The problems that exist are complex and the solutions are complex as well. Unequal distribution of resources and poor attitudes about mathematics stretch across all age groups. Innovation in teaching should be recognized and rewarded. Successful efforts to reach out to and motivate students must be recognized and supported.

We all know that bringing quantitative literacy to our schools is only one facet of a complex solution. We also must bring a recognition and, more important, an appreciation, of quantitative knowledge to our daily lives. This is important particularly for adults. People will seek out knowledge that directly affects them. As proof, they are already gravitating to science topics on primetime TV. Shows produced by National Geographic, Discovery, the Learning Channel, and others draw devoted audiences. NSF is proud to support dynamic children's shows such as "The Magic School Bus," "Bill Nye the Science Guy," and "Find Out Why," a series coproduced with Walt Disney Television Animation for broadcast between Saturday morning cartoons.

All these efforts recognize that everybody confronting a topic for the first time has difficulty. As Ralph Waldo Emerson said, "The secret of education lies in respecting the pupil." Many audiences come to the table with misconceptions and preconceptions, some of which can be shocking—but they need to be respected if we are ever to reach them.

Our efforts should focus on greatly expanding the number of Americans motivated to pursue quantitatively vigorous careers while also abolishing the general mathematics phobia that is pervasive in our society. If we present mathematics in a comfortable way, and even with humor, there is no reason we cannot reverse the present trend.

We can look at numeracy through the metaphor of an analog clock. Some people only need to know how to read the face to accomplish their daily goals. Some need to know that beneath the front a complex system of gears tracks the progression of time. Others need to be able to take the existing clock and innovate, to build the next generation of timekeeping devices. But who needs which information? And is knowledge of gear ratios necessary to appreciate the beauty and simplicity of the clock's face?

I would argue that some of us may be interested in knowing the deepest intricacies of timekeeping, yet we should not spend exhaustive resources teaching every intricate detail to every single person. The more critical lesson is on the clock's face, the thought process, the discovery process. Everyone needs to know how to tell time.

We must set flexible goals for literacy based on standards that are appropriate for every audience. We must recognize that most Americans are unaware of how mathematics permeates their lives. We must find ways of bringing their daily quantitative activities into focus. And most important, we must understand that literacy has levels.

And so we come full circle to the question, are we making progress? Recognition of the problem was the obvious first step. NSF's systemic initiatives mark significant progress. This conference and your hard work are testament to progress. Industry's concern and support is a mark of progress, and so are many other efforts.

Will we ever be able to say we have reached the finish line? Absolutely not. The finish line is a moving target and we must perpetually pursue it if we are to stay out front as individuals and as a nation. Who knows what the quantitative literacy needs of society will be in 2050 or the year 3000?

Notes

1. Angered by a 1791 federal excise tax on whiskey, farmers in the western counties of Pennsylvania began attacking tax agents. On August 7, 1794, President George Washington issued a proclamation, calling out the militias to respond. Thirteen thousand troops led by Washington and General Harry Lee, Robert E. Lee's father, quelled the uprising. This was the first use of the Militia Law of 1792, setting a precedent for the use of the militia to "execute the laws of the union,

[and] suppress insurrections," and asserting the right of the national government to enforce order in one state with troops raised in other states. Even more important, it was the first test of power of the new federal government, establishing its primacy in disputes with individual states. [Adapted from August 11, 1794, *Claypoole's Daily Advertiser*.]

2. On March 30, 1867, Secretary of State William H. Seward agreed to purchase relatively unexplored Alaska from Russia for $7 million. At the time, critics thought Seward was crazy and called the deal "Seward's folly." Major discoveries of gold were made there in the 1880s and 1890s. These discoveries brought attention and people to Alaska. Today, petroleum transported across the state through a pipeline is Alaska's richest mineral resource. [AmericasLibrary.gov, Library of Congress.]
3. Jethro Tull (farmer, 1674–1741) designed a machine (a seed drill) to plant seed more efficiently, minimizing the number of workers needed to sow a field. His system was a major influence on the agricultural revolution. [From BBC history.]
4. *Jethro Tull* (band, 1968–present), famous for flute-heavy tunes and such hits as "Aqualung" and "Living in the Past."

References

Bernstein, Peter L. 1996. *Against the Gods: The Remarkable Story of Risk.* New York, NY: John Wiley.

Tufte, Edward R. 1983. *The Visual Display of Quantitative Information.* Cheshire, CT: Graphics Press.