Reading, Writing, and Numeracy

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Liberal Education, 86:2 (Spring 2000) 26-37

Liberal Arts in Practice

In the first and second centuries B.C.E. (Before the Computer Era), literacy served as the principle sign of erudition and education. Familiarity with the great works of history, philosophy, art, and literature, capacity to speak and write more than one language, and fluency in oral and written communication were the hallmarks of a cultured, literate citizen. These were the tools by which individuals lived and society functioned.

Although no less important than in earlier eras, literary accomplishment by itself is no longer a sufficient warrant for a well-educated citizen in the middle of the first century C.E. In the Computer Era, familiarity with quantitative methods and computer processes has become as important as fluency in language and appreciation of fine arts. As the enlightenment thrived on literacy, the information age thrives on numeracy.

Indeed, numbers, data, and statistics both enrich and confuse our lives. Percentages, graphs, and indexes dominate news coverage of current events, from medical reports to political trends, from financial advice to social policy. Quantitatively based decisions abound in education, health, and government, while advertisers inundate consumers with conflicting quantitative claims about costs or effectiveness of new products. Numbers not only quantify the measurable (distance, weight, time) but also the immaterial (intelligence, risk, health). As the printing press nurtured demand for literacy in the centuries B.C.E., so computers have made numeracy a benchmark of educated citizenship in the modern age.

Unfortunately, despite years of study and experience in an environment drenched in data, many educated adults remain functionally innumerate. Most U.S. students leave high school with mathematical skills far below even minimum expectations; businesses lament the lack of technical and quantitative skills of prospective employees; and virtually every college finds many of its students in need of remedial mathematics. No one is surprised any longer by the news that U.S. high school graduates are, on average, far below par in mathematical and quantitative skills. But this commonplace hides a more disturbing reality: a vast gulf between many students who are superbly prepared and many more who enter college, and life, virtually uneducated in high school mathematics.

Numeracy in everyday events

In this new century, numeracy will matter as much as literacy. Quantitative, mathematical, and logical analyses undergird many routine events of everyday life, at home, at work, and in civic affairs. The most common are not archetypal "math problems" such as finding the cost of wallpapering a room where measurement and calculation lie visible on the surface. Instead, quantitative issues tend to lie beneath the surface of common events, awaiting the numerate observer to detect their presence:

- Negotiations are constantly in the news, from the Middle Eastern peace process to labor-management contract disputes, from divorce agreements to estate settlements. Many methods for balancing desires and dividing assets are known, some quite ancient (e.g., have one party divide the total assets and let the other party choose). Modern variations have improved on these ancient methods and are used routinely by professional negotiators. Importantly--and perhaps surprisingly-the reliability and fairness of these algorithms are established in an axiomatic manner analogous to that used by Euclid to establish the laws of geometry. With these deductive methods one can show, for example, that the "adjusted winner" method--one of the newest strategies--yields a result in which neither party envies the other's share, both parties place equal value on their shares, and no other arrangement could be better for both.
- Each day the news informs us of the daily highs and lows of two important indicators: the outdoor temperature and the Dow Jones average. Most people think these are analogous indicators, one of the weather, the other of the stock market. However, temperature is a generally a single reading recorded at a specific location, typically a major airport, whereas the Dow is an average of certain stocks which may or may not represent the market as a whole. Moreover, contrary to the way it is often used in headlines, the Dow is not a measure of the total value (capitalization) of the stock market but merely an average of stock prices.
- Major newspapers recently headlined a report published in the New England Journal of Medicine showing that doctors were only 60 percent as likely to order a potential life-saving heart test for women and blacks as for men and whites. This startling conclusion was arrived at by calculating the ratio of two odds--the odds of blacks being referred for the test to the odds of whites being referred for the test. But this ratio, it turns out, is both counterintuitive and highly misleading. If one uses instead a simpler ratio, for example, the percentage of blacks referred for the test to whites referred for the test, the result is rather different: 93.5 percent. Neither journalists nor editors seemed to realize that different ratios derived from the same data would yield dramatically different headlines.
- When state troopers on the New Jersey turnpike were accused of racial profiling--discriminating against African-American drivers by singling them out for traffic stops--police records showed that in 70 percent of the stops, the race of the driver was not recorded while in the 30 percent of the stops where race was indicated, blacks were nearly five times as likely as whites to be driving. Lawyers and statisticians were able to resolve the uncertainties of this evidence by using Bayes Theorem, a statistical tool that enhances deductions from raw data with prior knowledge based on other studies--in this case, evidence of whether race was more likely to be recorded when the driver was black.
- Drug companies now flood the airwaves with advertisements for new prescription medicines. Consumer pressure dramatically increases sales of advertised drugs, as well as related costs to HMOs, Medicare, and consumers. In one recent example cited by ABC World News, clinical trials were said to reduce the risk of serious consequences from heart attacks by up to 33 percent. Yet the data behind this study show that only six out of one hundred patients suffered a heart attack, and two of them had reduced symptoms. So of those who suffered heart attacks, one-third had reduced symptoms. But of those who took the medicine, only 2 per cent received the benefit of reduced symptoms during a heart attack. How many people who hear these advertisements understand that the claim

of 33 percent "reduced risk" might really mean only 2 percent chance of benefit for an average person?

- In the last half of the eleventh inning of the dramatic sixth game of the 1999 National League championship series between the Atlanta Braves and the New York Mets, the Braves had runners on first and third with two outs and a .330 hitter at the plate. Following long-established conventional wisdom, the Mets issued an intentional walk, loading the bases in return for pitching to a .271 hitter. The result was disaster for the Mets: the weaker batter walked in four straight pitches and the Mets lost both the game and the championship. More refined analysis of the odds shows that the intentional walk in these circumstances is not a good bet. Managers continue to call for it, however, since like everyone else they are motivated more by subjective probability than by actual risk--in this case, that of a weak hitter managing to get on base without actually hitting the ball.

Numeracy as a liberal art

Faced with enormous variation both in the demand for quantitative literacy and in its supply (that is, in the quantitative capabilities of incoming students), colleges have responded with highly varied expectations for their graduates (see Sidebar, page 29). Some require specific courses with limited goals (e.g., college algebra), while others offer a choice of courses with significantly different goals (e.g., statistics, calculus, mathematics for liberal arts); some require passing a locally written (and rarely validated) proficiency examination, others offer exemptions based on above-average SAT scores; some focus on courses in mathematics, others on mathematics across the curriculum; some require either mathematics or science, others both; and some impose no quantitative requirement of any kind whatsoever.

This disorderly array of requirements reveals profound confusion about goals for quantitative literacy (see Sidebar page 30). Historically, quantitative literacy was not one of the traditional priorities of liberal education. Although mathematics and statistics courses have been widely required as prerequisites for the study of science and business, and sometimes prescribed on a college-wide basis, little thought has been given to the role of quantitative literacy in the lives of educated citizens. As a consequence, the required mathematics courses that most students take in college rarely enhance their quantitative literacy and make little impact on their subsequent lives.

One notable response to this pattern of neglect was the "New Liberal Arts" (NLA) initiative begun in 1980 by the Alfred P. Sloan Foundation. This decade-long program sought to give computing, quantitative reasoning, and applied mathematics a central place in liberal education, not as separate courses but as a commitment to quantification throughout the arts and humanities. In an effort to seed the terrain of higher education with quantitatively-rich courses in the arts and humanities, the Sloan Foundation supported dozens of innovative courses at selective liberal arts colleges (see Sidebar, page 32).

A similar initiative, motivated, however, more by concern for mathematics than for liberal education, is the National Science Foundation's program called Mathematical Sciences and their Applications Throughout the Curriculum (MATC). This initiative, funded for only one round of competition in the mid-1990s, supported mathematically-enriched courses on dozens of campuses through grants to a few regional consortia (see Sidebar, page 33). Like the NLA projects of the 1980s, the MATC projects of the 1990s sought to embed contemporary quantitative methods in courses where such use was relatively unprecedented. In addition, MATC also sought to enhance the quality and effectiveness of mathematical applications in curricular areas that were well accustomed to employing mathematical or statistical techniques.

Goals and Objectives

Opportunities for quantitative thinking in personal and civic affairs are diverse, pervasive, and compelling. College requirements for quantitative literacy are also diverse and pervasive, but hardly compelling. Whereas traditional mathematics courses such as calculus or statistics benefit from relatively clear purposes about which professionals generally agree--as much as academics agree on anything--requirements concerning numeracy or quantitative literacy rest on no such consensus.

Between the lines of the stated rationales for quantitative literacy requirements and the syllabi of the courses used to meet these requirements, one finds a wide variety of goals, including:

- Algebra for All: Credit for intermediate or college algebra.
- Civic Literacy: Informed skepticism about uses of quantitative data.
- Computer Mathematics: Proficiency in spreadsheets, financial, and graphical tools.
- Cultural Literacy: Appreciating the nature, history, and influence of mathematics.
- Functional Mathematics: Solving problems commonly encountered in life and work.
- Instrumental Mathematics: Using mathematical tools to predict, plan, and control.
- Language of Science: Mastery of mathematical techniques used by scientists and engineers.
- Mathematical Modeling: Using mathematical models to solve real-world problems.
- Mathematics in Context: Applying mathematics to problems in very specific situations.
- NCTM Standards: Understanding and use of a broad range of mathematics, nominally K-12.
- Parental Literacy: Mathematical skills and attitudes parents can use to help their children.
- Preparation for AP: Traditional high school mathematics skills, well practiced.
- Problem Solving: Thinking mathematically about ordinary events.
- Quantitative Practice: Habitual patterns of action routinely performed.
- Quantitative Reasoning: Logical thinking and mathematical habits of mind.
- Reduced Anxiety: Diminishing the negative effects of school-grown "math anxiety."
- SCANS Skills: Using and managing information, resources, systems, and technology.
- Statistical Thinking: Summarizing data, drawing inferences, presenting conclusions.
- Test Scores: Scoring above the mean on the SAT, ACT, or some locally written test.

Notwithstanding this enormous diversity of goals and objectives, on two issues there appears to be significant agreement: First, quantitative literacy is not achieved in traditional courses. Second, quantitative literacy is not the same as mathematics.

For many students and adults, mathematics is something you do in math class--typically, performing algorithms and manipulating formulas, generally without meaningful contexts. Mathematics in math class channels students into a curricular tunnel leading directly from elementary algebra to calculus with little opportunity to experience the breadth of quantitative methods appropriate for an educated citizen. In contrast, quantitative literacy aims to be a part of routine living, a powerful tool regularly used for making decisions about ordinary things in everyday life. In this respect--numeracy for life vs. numeracy for class--there is remarkably little connection between the goals of quantitative literacy and the accomplishments of courses that teach traditional mathematics.

Whereas the mathematics curriculum has historically focused on school-based knowledge, quantitative literacy involves mathematics in action. Typical numeracy tasks involve real data and uncertain procedures but require only simple mathematics; typical mathematics problems involve simplified numbers and straightforward procedures, but require sophisticated abstract concepts.

It is thus not too surprising that traditional mathematics courses such as college algebra and calculus leave many very capable students unprepared for even simple data analysis. Even Harvard students encountered significant difficulty in dealing with a multiple choice, high school level, data analysis test that was, until just recently, a requirement for graduation. Nearly half the students, many of whom had passed AP Calculus, failed their first try at this test. Too many had been conditioned to think of mathematical techniques as memorizable procedures. According to one study, many students had to relearn how to work with decimals and percentages. Many didn't think of a number as meaningful; saying that 83 percent of 60 is 4.98 was to them just as acceptable as 49.8. Surprisingly many of these students--representative of the best undergraduates in the nation--reached for their calculators when asked to find l0% of 100.

While it is not surprising to find that decontextualized courses devoid of real data leave students unprepared for the quantitative challenges of daily life and further study, we might be justified at expressing some surprise at the continuing (and often unexamined) pattern of colleges requiring such courses in the name of liberal education. Part of the explanation probably lies in attitudes of mathematicians who often view quantitative literacy as a distraction, dilution, or corruption of mathematics. Mathematicians are more willing to support a requirement based on their view of real mathematics than a requirement designed to make mathematics real in students' lives.

Mathematicians are wont to think primarily about "mathematical literacy" which in their eyes is something very different from what we have been calling "quantitative literacy." In contrast to quantitative literacy, which focuses on the needs of citizens in a data-intensive society, mathematical literacy offers students a panorama of the venerable discipline of mathematics, anchored in the language of algebra and geometry, generally more symbolic than numeric, more historical than contemporary. Valuable as this may be, it is rarely what most students seek or what faculty in other departments have in mind with a QL requirement. For this reason, on many campuses the most vigorous advocates of effective quantitative literacy are faculty outside mathematics departments who have less commitment to the discipline of mathematics and more need for students to be able to think quantitatively.

Options for QL requirements

Historically, the most common course used to satisfy a mathematical or quantitative requirement is college algebra, a tedious course full of what one university mathematician described as "Kafkaesque algebraic manipulations" that are irrelevant for the vast majority of students. The strongest argument in favor of college algebra is that mastery of algebra at this level opens doors to many quantitatively based subjects. However, this argument applies primarily to students who take the subject while in high school. Most college students who use college algebra to fulfill a requirement are already well on their way to a major that doesn't make use of what they learn in this course. And virtually none of the things that they will really need to know to serve their communities and enhance their careers is found in college algebra.

Another common form of QL requirement is to pass an examination, often the mathematics part of the SAT or some locally written test. Rarely do such tests cover much more than manipulative and procedural knowledge. Moreover, by their very nature, they reward test-taking skills more than the practical insights of a truly numerate citizen. What's worse, many institutions illogically pass students who do well on the SAT (which requires only elementary algebra) while requiring those who do poorly to enroll in intermediate or college algebra--courses that require elementary algebra as a prerequisite.

Another common option is the smorgasbord: a selection of quantitatively intense courses from which students choose one or two. This approach has many advantages: options for students, variety for faculty, simplicity for administrators. But it does leave many students with very weak QL skills, particularly those who satisfy the requirement with an option such as algebra or calculus that avoids entirely the subtleties of reasoning with data. Credit-based requirements of this sort help promote a kind of collective numeracy among college graduates without attempting to ensure that each individual graduate is quantitatively literate. This may be all that most colleges can realistically expect to accomplish.

A few institutions include quantitative literacy in a core curriculum required of all students, but even these programs often find that for practical and political reasons they must exempt advanced mathematics students (e.g., those taking calculus) from the core requirement. The core then becomes a tracking system: science and engineering students take traditional courses, arts and humanities students take the QL core course. Thus, despite idealistic intentions, core curricula generally forfeit the benefits of robust interaction on the role of quantitative reasoning among students with very different majors.

The stark fact is that most college requirements fail to fulfill any but the most limited goals of quantitative literacy. Many students actually leave college less numerate than when they entered, having studied for four or more years in courses that neither extend nor reinforce whatever numeracy skills they may have learned in high school. (Unfortunately, many of these graduates will go on to careers in teaching where they will perpetuate the cycle of quantitative avoidance and innumeracy.) Neither college algebra nor exam requirements, neither quantitative courses nor core curricula can fulfill more than a tiny fraction of the quantitative needs of educated citizens in the computer era. To reflect the reality of numeracy as the literacy of our age, quantitative literacy needs to become as pervasive in the curriculum as are reading and writing.

Pioneering efforts such as the NLA and MATC programs demonstrate both that mathematical and quantitative ideas do permeate courses all across the campus, albeit often invisibly, and that students who learn mathematics in the context of such courses do achieve many of the goals of quantitative literacy. When students employ quantitative reasoning and mathematical methods as routinely as they now read and write, when students see numeracy as a natural component of learning in multiple contexts, when logical thinking and numerical estimates are part of virtually every course--then and only then will students graduate from college as numerate citizens. Only by making quantitative ideas as pervasive in the curriculum as they are in life will numeracy become, like literacy, part of the fabric of liberal education. And only then will liberal education truly prepare students for life in the Computer Era.

A Sampler of College QL Requirements

Examples of quantitative and mathematical requirements in four-year colleges. More detailed descriptions of QL requirements and campus support systems can be found on the Internet at <http:www.stolaf.edu/other/ql/reqs.html>.

Bowdoin College: Requires a diagnostic quantitative skills test followed by recommendations for non-mandatory courses to remedy deficiencies.

California State University, Fullerton: Requires any 3-4 (post-remedial) credits in mathematics.

Clark University: Requires one "formal analysis" course (e.g., calculus or statistics) after qualifying with a score of at least 520 on the mathematics part of the SAT, passing a locally written test, or passing a proficiency course in Quantitative Thinking.

DePauw University: Requires one quantitative reasoning course selected from among a set of courses certified for this purpose by a faculty-wide committee.

Hamilton College: Requires either a score of at least 50 percent on a quantitative skills exam, passing a course designated as having a significant quantitative component, or completing a non-credit quantitative literacy tutorial. All students must also take two courses in mathematics or science.

Harvard College: Requires one course in Quantitative Reasoning offered in the Core Curriculum. (Until recently, students were expected to demonstrate competence in data analysis and computer use by means of a non-credit test and project.)

New York University: Requires "Understanding the Mathematical Patterns in Nature," a course in quantitative reasoning Which serves as the first of three courses in the core program "Foundations of Scientific Inquiry."

Sam Houston State University: Requires a single three-hour course whose goal is to develop problem-solving skills. (Until recently, students were required to complete two three-hour quantitative literacy courses, typically one in college algebra and one in introductory computing.)

Trinity College (CT): Requires passing four parts of a mathematical proficiency exam or completing corresponding proficiency courses offered by the Quantitative Literacy Center.

University of Colorado, Denver: Requires either college algebra and calculus or one course in mathematics for liberal arts students and one course in computer literacy.

University of Massachusetts, Boston: Requires either passing a quantitative test, or an algebra course that is the prerequisite for precalculus, or a new quantitative reasoning course that is the prerequisite for other mathematics and statistics courses.

University of Nevada-Reno: Requires one mathematics course selected from a range of options (e.g., liberal arts mathematics, college algebra, elementary statistics). In addition, locally developed diagnostic "gateway exams" serve as prerequisites for courses that employ quantitative skills.

University of Oregon: Requires either 3 quarters of mathematics (for B.S. candidates) or a foreign language (for B.A. candidates). Traditionally, college algebra (or calculus) was used to meet the requirement; recently, a new course on more practical mathematics has been introduced.

What is Quantitative Literacy?

Perspectives on quantitative literacy drawn from essays in *Why Numbers Count: Quantitative Literacy for Tomorrow's America* (College Board, 1997).

• Understanding the role of numbers in the world. QL provides the ability to see below the surface and get at real issues.

--Ted Porter, historian.

• Competencies that can be used to solve problems people would frequently encounter on the job or in their roles as citizens or parents.

--Arnold Packer, economist.

• Understanding mathematical concepts and skills that are critical for life in : the contemporary world: computation, interpretation, inquiry, and application.

--Glenda Price, provost.

• Real world problem solving--the use of mathematics in everyday life, on the job, and as an intelligent citizen.

--Henry Pollak, applied mathematician.

• Habitual patterns of actions engaged in routinely, usually without thought, involving numbers, uncertainty, data, experiments, models, validations, inferences, tradeoffs.

--Peter Denning, computer scientist.

• Knowing how to reason and how to think how to analyze evidence, understand arguments, detect logical fallacies, and evaluate risks.

--Gina Kolata, journalist.

• Understanding the nature of mathematics and its role in scientific inquiry and technological progress.

--F. James Rutherford, physics educator.

• An aggregation of skills, knowledge, beliefs, dispositions, habits of mind, communication capabilities, and problem solving skills.

--Iddo Gal, cognitive scientist.

• An interpretive activity that takes place within a deductively structured framework. In QL, context provides meaning.

--George Cobb, statistician

The New Liberal Arts

In the late 1970s, as American public attention was focused on rising inflation, oil embargoes, and the Iran hostage situation, entrepreneurial pioneers on the West Coast of the United States invented personal computing. Between 1977 and 1979, Steven Jobs created the Apple computer; Bill Gates and Paul Allen founded Microsoft; Bob Metcalfe invented Ethernet; Hayes marketed the first modern; Epson created an affordable dot-matrix printer; Intel introduced the 8088 chip, a 16-bit processor; Dan Bricklin and Bob Frankston introduced the spreadsheet Visicalc; and WordStar, the first word processor and the database program dbase were created. In 1980 Ronald Reagan was elected president, Steve Ballmer joined Microsoft; IBM initiated a crash program to develop a personal computer; and Microsoft agreed to provide the operating system. Few then realized how the world had changed.

One of those who had a glimmer of the revolution to come was Stephen White, vice-president of the Alfred P. Sloan Foundation. In 1980, White argued in an internal memorandum entitled "The New Liberal Arts" that in the late twentieth century the tools of technology-computing, quantitative reasoning, applied mathematics--deserve a central place in liberal education. White argued that just as a century earlier science claimed a central place in the undergraduate curriculum, so at the dawn of the twenty-first century these "new liberal arts" deserve a similar role--not as separate courses or departments, but as a commitment to quantification and technology infused throughout the arts and humanities. Not only are these studies essential for the nation's economic vitality, but they provide perspectives that responsible citizens must have.

In support of these ideas, the Alfred P. Sloan Foundation awarded over $20 million in grants during the 1980s to liberal arts colleges for curricular initiatives that infused quantitative methods in courses in the humanities and social sciences. Examples of courses or modules supported in this initiative include: Vaccines: An Introduction to Risk (Claremont); Garbage and Trash (Stony Brook); Witchcraft: History and Statistics (Mount Holyoke); Chemistry and Crime (Williams); and Management of Public Risk (Brandeis). In addition, several books based on NLA courses were published jointly by McGraw Hill and MIT Press including, for example, Medical Technology and Society (Bronzino, Wade, and Smith); Understanding Quantitative History (Haskins and Jeffrey); Light, Wind, and Structure: The Technology of Historic Architecture (Mark); and The Age of Electronic Messages (Truxal).

Mathematical Sciences and their Applications Throughout the Curriculum

As a sequel to its support of calculus reform, in the mid-1990s the National Science Foundation awarded grants to several higher education consortia to demonstrate how instruction in the mathematical sciences could be improved by incorporating other disciplinary perspectives. Seven projects were funded in this program known as Mathematical Sciences and their Applications Throughout the Curriculum (MATC):

The University of Pennsylvania. Middle Atlantic Consortium for Mathematics and Its Applications Throughout the Curriculum. Goals: to integrate research and real-world applications into the basic mathematics curriculum and to achieve effective integration of advanced mathematics and computing into upper-level curricula.

Web: www.math.upenn.edu/~ugrad/macmatc

Rensselaer Polytechnic Institute. Project Links. Goals: to produce instructional materials for use in workshop or studio-type courses and to create a library of materials that link topics in mathematics with applications in engineering and science.

Web: www.links.math.rpi.edu/webhtml/overview.html

Dartmouth College. Goals: to thoroughly integrate the study of mathematics with courses in the natural and social sciences, economics, art, music, philosophy, computer science, architecture, medicine, engineering, and literature.

Web: www.dartmouth.edu/~matc

Indiana University. Goals: to create interdisciplinary courses involving mathematicians and faculty from a variety of disciplines, to change students' attitude toward mathematics, and to make permanent positive cultural changes in the teaching and learning of mathematics.

Web: www.math.iupui.edu/ aboutICUE.html

Oklahoma State University. Goals: to create a model mathematics laboratory, a regional technology assistance center, summer academies for high school students, and a project on multimedia mathematics across the curriculum and across the nation.

Web: www.math.okstate.edu/ archives/projects.html

State University of New York at Stony Brook. The Long Island Consortium for Interconnected Learning. Goals: to enhance the learning environment and increase faculty cooperation in quantitative disciplines, and to create synergy through simultaneous change in modes of instruction, educational technology, and coordination among departments.

Web: www.licil.org/

U.S. Military Academy at West Point. Project Intermath. Goals: to change faculty culture in all mathematics courses in the spirit of the calculus reform movement and to develop interdisciplinary small-group applications projects using faculty from more than one discipline.

Web: www.dean.usma.edu/ math/intermath/index.htm

Recommended Reading:

Bernstein, Peter L. 1996. *Against the Gods: The Remarkable Story of Risk*. New York: John Wiley. How gaining control over the quantification of risk led to the rise of modern business.

Devlin, Keith. 1994. *Mathematics: The Science of Patterns*. New York: Scientific American Library. A lavishly illustrated survey of the landscape of mathematics, both ancient and modern.

National Council of Teachers of Mathematics. 2000. *Principles and Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics. A substantive set of goals for school mathematics, revised from the 1989 original publication.

Paulos, John Allen. 1996. *A Mathematician Reads the Newspaper*. New York, NY: Doubleday. Examples of numeracy and (mostly) innumeracy in the daily news.

Paulos, John Allen. 1988. *Innumeracy: Mathematical Illiteracy and its Consequences*. New York: Vintage Books. The book that first brought the problem of innumeracy to public attention.

Porter, Theodore M. 1995. *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton, NJ: Princeton University Press. A scholarly history of how the increasing use of numbers and data enabled (and was motivated by) the rise of centralized governments.

Steen, Lynn Arthur, ed. 1997. *Why Numbers Count: Quantitative Literacy for Tomorrow's America*. New York: The College Board. Essays by leaders in different fields offering very different visions of quantitative literacy.

Tufte, Edward R. 1983, 1990, 1997. *The Visual Display of Quantitative Information; Envisioning Information; Visual Explanations--Images and Quantities, Evidence and Narrative*. (3 vols.) Cheshire, CT: Graphics Press. A stunning set of volumes showing how data and information can be communicated visually.

Wise, Norton M., ed. 1995. *The Values of Precision*. Princeton, NJ: Princeton University Press. A collection of scholarly essays examining how exactitude came to be so valued in Western culture.

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