

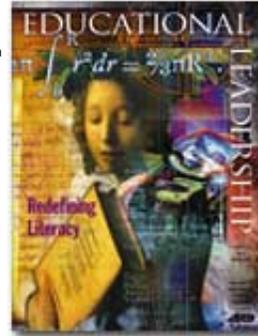
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Numeracy: The New Literacy for a Data-Drenched Society

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To develop an informed citizenry and to support a democratic government, schools must graduate students who are numerate as well as literate.



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The age of information is an age of numbers. Data, graphs, and statistics both enrich and confuse our lives. Numbers and quantities overwhelm current events, from medical reports to political trends, from financial advice to social policy. News is filled with charts and graphs, while quantitatively based decisions control education, health, and government.

Nonetheless, national and international studies show that most U.S. students leave high school with far below even minimum expectations for mathematical and quantitative literacy. Businesses lament the lack of technical and quantitative skills of prospective employees, and virtually every college finds itself teaching a wide range of remedial mathematics. Despite years of study and experience in an environment drenched in data, many educated adults remain innumerate.

Quantitative literacy—or numeracy, as it is known in British English—means different things to different people. Although quantitative literacy is often confused with its close relatives, such as basic skills, elementary statistics, logical reasoning, or advanced mathematics, none of these by itself offers a complete or balanced view of numeracy (Steen, 1990, 1997). Rarely mentioned in national standards or state frameworks, numeracy nonetheless nourishes the entire school curriculum, including not only the natural, social, and applied sciences, but also language, history, and fine arts. Unfortunately, little numeracy is taught anywhere except in mathematics classes, and not as much as one might expect is taught (much less learned) even there.

In colleges and universities—where K–12 teachers are educated—confusion about quantitative literacy is profound. Institutions differ widely in the extent to which they expect graduates to be quantitatively literate. Some require specific courses (for example, college algebra), whereas others offer a choice of courses with significantly different purposes (for example, statistics, calculus, mathematics for liberal arts); some require a proficiency examination, others offer exemptions on the basis of strong SAT scores; some focus on courses in mathematics, others on numeracy across the curriculum; some require mathematics or science, others both; and some impose no quantitative requirement of any kind.

In contrast, the internationally competitive, high-performance industries on which the U.S. economy depends are unequivocal about quantitative literacy. They now expect of most entry-level employees quantitative skills that exceed not only what commercial or vocational education has traditionally included, but also even what most colleges expect of their own graduates (BCER, 1998). Statistical, computer, interpretive, and technical communication skills are the

staples of modern business (SCANS, 1991) but are rarely found among high school or college graduates because they are rarely required. These tools, and others, are essential parts of the contemporary definition of quantitative literacy.

As quantitative methods have become increasingly important in work and life, so have they come to play a major role in education. No longer is mathematics a requirement only for prospective scientists and engineers; now some degree of mathematical or quantitative literacy is required of anyone entering the modern high-performance workplace or seeking advancement in a career (MSEB, 1995). Indeed, most future jobs will require skills associated with higher-order quantitative thinking, although not necessarily those found in a typical mathematics curriculum (Judy & D'Amico, 1997; Packer, 1997).

Yet despite widespread evidence that numeracy is more than mathematics and that practical wisdom is not the same as classroom learning, anxious parents and politicians push students into the narrow gorge of early algebra and high school calculus in the misguided belief that these courses provide the quantitative skills appropriate for educated citizens. By and large, they do not. Even individuals who have studied calculus remain largely ignorant of common abuses of data and all too often find themselves unable to comprehend (much less to articulate) the nuances of quantitative inferences (Cohen, 1989; Huff, 1954/1993; Paulos, 1996). Numeracy, not calculus, is the key to understanding our data-drenched society.

A Brief History of Numeracy

Although the discipline of mathematics as a logical system of axioms, hypotheses, and deductions has a very ancient history, the expectation that ordinary citizens be quantitatively literate is primarily a phenomenon of the late 20th century. In ancient times, numbers—especially large numbers—served more as metaphors than as measurements. The importance of quantitative methods in human affairs emerged very slowly in the Middle Ages as artists and merchants learned the value of imposing standardized measures of length, time, and money on their arts and crafts (Crosby, 1997).

In colonial America, such leaders as Benjamin Franklin and Thomas Jefferson promoted numeracy to support the new experiment in popular democracy, even as skeptics questioned the legitimacy of policy arguments based on empirical rather than religious grounds (Cohen, 1982). Only in the latter part of this century have quantitative methods achieved their current status as *the* dominant form of acceptable evidence in all areas of public life (Bernstein, 1996; Porter, 1995; Wise, 1995). Out of origins in astrology, numerology, and eschatology, numbers have become the chief instruments through which we attempt to exercise control over nature, over risk, and over life itself.

As the gap between citizens' quantitative needs and resources has widened, many researchers have sought to explain to the public the nature of numeracy, its benefits, and possible strategies for improvement. Popular books, such as *Overcoming Math Anxiety* (Tobias, 1993), *Innumeracy* (Paulos, 1988), and *Math Panic* (Buxton, 1991), raised public awareness of the consequences of innumeracy, even as Edward Tufte's extraordinary volumes (1983, 1990, 1997) revealed the unprecedented communicative power of visual displays of quantitative information.

In recent years, dozens of informative books have appeared, ranging from surveys of core mathematics (for example, Dunham, 1990; Devlin, 1994; Singh, 1997) to practical perspectives (Bolt, 1991; Steen, 1997). These volumes reveal considerable confusion about the nature of quantitative literacy, especially about its relation to mathematics. They echo and amplify the historical dichotomy of mathematics as academic and numeracy as commercial.

In 1989, the National Council of Teachers of Mathematics published national standards for school mathematics (NCTM, 1989) that present a significantly enhanced vision of mathematical skills and advanced problem solving intended for all high school graduates. These standards are being revised for republication in April 2000; a draft (NCTM, 1998) is currently under public review.

Ironically, these standards—still much debated and largely unimplemented—exceed what most colleges and universities dare require even of their graduates.

Valuable as the NCTM standards document may be in prodding schools to improve their *mathematics* curriculum, it does not provide definitive guidance on the *numeracy* needs of tomorrow's students and citizens. Examples of the latter—of quantitative methods used in other areas of education and work—can be found in the standards for other subjects, notably in science (NRC, 1998; Project 2061, 1993), history (NCHS, 1996), geography (NGS, 1994), and social studies (NCSS, 1994), as well as in recently published occupational skill standards (NSSB, 1998) in such areas as bioscience (EDC, 1995), electronics (AEA, 1994), health care (FarWest Laboratory, 1995), and photonics (CORD, 1995). For those who are prepared to detect hidden evidence of the need for quantitative literacy, these reports abound with relevant footprints.

Notwithstanding the immense value of numeracy for education and vocation, its most profound value to society may be the role it plays in supporting informed citizenship and democratic government. Virtually every major public issue—from health care to Social Security, from international economics to welfare reform—depends on data, projections, inferences, and the kind of systemic thinking that is at the heart of quantitative literacy. So too are many aspects of daily life, from selecting telephone services to buying a car, from managing household expenses to planning for retirement. For centuries, verbal literacy has been recognized as a free citizen's best insurance against ignorance and society's best bulwark against demagoguery. So today, in the age of data, quantitative literacy joins verbal literacy as the guarantor of liberty, both individual and societal.

Quantitative Literacy in School

Quantitative literacy is both more than and different from mathematics—at least as mathematics has traditionally been viewed by school and society. Many basic mathematical skills are essential for numeracy, including arithmetic, percentages, ratios, simple algebra, measurement, estimation, logic, data analysis, and geometric reasoning. But so too are other concepts not normally emphasized in traditional school mathematics (Forman & Steen, 1999):

- estimating tolerances and errors;
- simulating complex systems on computers;
- using flowcharts for planning and management;
- drawing inferences appropriately (statistical, scientific, logical);
- presenting data-based arguments by using modern computer tools;
- thinking, visualizing, and calculating in three dimensions.

However, numeracy is not just an expanded list of topics to be added to the mathematics curriculum. The test of quantitative literacy, as of verbal literacy, is whether a person naturally uses appropriate skills in many contexts. Educators know all too well the common phenomenon of compartmentalization, in which skills or ideas learned in one class are totally forgotten when they arise in a different context. Students need to learn numeracy in multiple contexts—in history and geography, in economics and biology, in agriculture and culinary arts.

Because numeracy is ubiquitous, opportunities abound to teach it across the curriculum. Unfortunately, the tradition in U.S. schools has been to teach mathematics as a subject separate from the rest of the curriculum and to focus high school mathematics on selecting and preparing students who intend to enter professions that require calculus. Both these traditions must be discarded if we are to make *all* high school graduates quantitatively literate.

First, all teachers must encourage students to see and use mathematics in everything they do: measurement in science, logic and reasoning in language and communication, ratios and rhythms in music, geometry in art, scoring and ranking in athletics. At the same time that

students are learning quantitative notions in mathematics class, teachers of other subjects should actively promote assignments and activities in which quantitative thinking is helpful: in reading maps, in designing art projects, in understanding rules of grammar, in analyzing scientific data, in interpreting evidence. All teachers need to help students think of mathematics not just as tasks on school worksheets but as something that arises naturally in many contexts. Mathematics teachers should not, and cannot, bear the entire burden of helping students become quantitatively literate.

Second, mathematics teachers, especially in grades 5–9, need to broaden their goals to encompass more than just the narrow arithmetic-algebra track that has historically dominated U.S. mathematics programs. In particular, they need to vigorously develop several parallel (and highly interconnected) strands of quantitative thinking:

- higher arithmetic (ratio, percentage, proportion);
- measurement geometry in two and three dimensions (length, area, angles, volume);
- data analysis (using elementary statistics, graphing data, estimating error);
- mental arithmetic (estimation, approximation, exact mental calculation);
- argument and persuasion (types of reasoning, using quantitative evidence);
- chance and risk (estimating probabilities, comparing and controlling risk);
- finding unknowns (by reasoning, manipulating symbols, or using models).

Before moving on to more advanced mathematics, such as trigonometry and calculus, all students should study the equivalent of one full year each of algebra, geometry, and elementary statistics. These three subjects, mutually reinforcing, frame the foundations of quantitative literacy. They may be either integrated or separated in particular curriculums, but even when they are taught separately, the links among them should be fully exploited.

Finally, to repeat the central issue of reinforced learning, high school teachers of every subject must use students' growing numeracy skills—especially in the natural, social, and applied sciences where the need for quantitative literacy is compelling. All teachers should make abundant use of inferences based on data and graphs; of reasoning based on linear equations; of geometric calculations, probabilistic inferences, and elementary statistics; and of argumentation based on logic and evidence. Only by using the diverse aspects of numeracy in real contexts will students develop the habits of mind of a numerate citizen. Like literacy, numeracy is everyone's responsibility.

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