EPILOGUE

# Embracing Numeracy

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The dawn of the third millennium occasioned unusual public interest in numbers, recalling earlier eras in which numbers were thought to have meanings that influenced or predicted world affairs. Sophisticates dismissed such talk as mere numerology, unbecoming the modern age in which numbers do our bidding, not us theirs. Computers, cell phones, DNA analysis, digital music, and video editing document our mastery of numbers that convey digitally coded instructions. Notwithstanding embarrassing worries about potential Y2K bugs, the high priests and roaring economy of the computer age offered living proof that the new millennium was indeed a new age. It surely seemed, at the turn of the twenty-first century, that by harnessing quantities to amplify our minds we had finally gained full control over the power of numbers.

Yet things are not always as they seem. Consider, for example, Americans' exercise of democracy in the year 2000. It began with political bickering about apportionment and the decennial census—an argument about how to count people. It then moved to the presidential campaign, in which candidates jousted about budgets and tax cuts, about Social Security and medical costs—raising arguments about how to count money. After the election it continued in the courts and the media as partisans contested the result—arguing endlessly about how to count votes.

We might view these events as the revenge of the numbers. It was the number counted ("actual enumeration"), not the people themselves, which would determine apportionment. It was numbers in a spreadsheet—projected surpluses—not actual revenue, which would determine government budget policy. And it was the number of votes tabulated, not the intentions of voters, which would elect the president. Everywhere we looked, numbers seemed once again to be in charge.

Counting people, counting dollars, and counting votes are part of the numeracy of life. Unlike the higher mathematics that is required to design bridges or create cell phones, counting appears to require only rudimentary arithmetic. To be sure, when large numbers, multiple components, and interacting factors are involved, the planning required to ensure accurate counts does become relatively sophisticated. So even though the underlying quantitative concepts are typically rather elementary—primarily topics such as multiplication, percentages, and ratios—the mental effort required to comprehend and solve realistic counting problems is far from simple.

## Numeracy and Mathematics

Contrary to popular belief, only a small part of the secret to control over numbers can be found in the mathematics curriculum. That is because skill in complex counting, like dozens of other examples mentioned in "The Case for Quantitative Literacy," is rarely developed in school mathematics. Once basic arithmetic is mastered (or more often, "covered"), the curriculum moves on to advanced and abstract mathematical concepts. Like other rigorous disciplines, mathematics in school advances inexorably toward increasingly sophisticated concepts required for higher education and subsequent professional use. Seldom do students gain parallel experience in applying quantitative skills in subtle and sophisticated contexts.

A chief message of this volume is that more mathematics does not necessarily lead to increased numeracy. Although perhaps counterintuitive, this conclusion follows directly from a simple insight: numeracy is not so much about understanding abstract concepts as about applying elementary tools in sophisticated settings. As the respondents to the case statement emphasize, this is no simple feat. Numeracy takes years of study and experience to achieve. Thus numeracy and mathematics should be complementary aspects of the school curriculum. Both are necessary for life and work, and each strengthens the other. But they are not the same subject.

Respondents to the case statement make this distinction very clear. "I deal with quantitatively argued issues virtually all the time," writes a historian and academic administrator. "But the truth is, there is no connection at all between the mathematics I took beyond arithmetic and the questions I face as a professional." This theme of regret is echoed even by a Ph.D. mathematician: "I was very 'well trained.' Nonetheless, the mathematics education that I received was in many ways impoverished." Another mathematician describes this frustration through the eyes of her students: "What was unexpected was the vehemence with which the students reacted to the scientific context [of a mathematics problem]. . . . They literally wore themselves out by unnecessary efforts." And a mathematics teacher wonders aloud about the motivation of parents: "Why are so many educated people so eager to visit upon their children what might reasonably be considered to be the mistakes of their past?"

The fact that many respondents resonated personally with the case statement's attempt to describe and highlight this new domain called quantitative literacy is itself significant. Each respondent had a similar experience with mathematics in school: canonical courses in the academic track taught with traditional templates and learned well enough to launch professional careers. But as these responses reveal, the challenge of the case statement stimulated in the respondents a sense of something missing, some important preparation for life that was ignored by this traditional mathematics education. The result is a series of uncommonly personal conversations about mathematics and numeracy, about their similarities and differences, their benefits and costs. The stories told in these responses illuminate an important human dimension of mathematics education that is seldom described in public.

Although the mathematics of Euclid and Newton has always held a place of honor in the curriculum, it is only in the last half-century that this particular mathematics came to be regarded as a core subject for everyone anticipating higher education when widespread applications of mathematics made the case for its importance both to individuals and to our nation. The role played by mathematical methods in World War II, the Cold War, the Space Race, and the Computer Age created an unassailable warrant for school mathematics. Apart from English, mathematics is now the most widely taught subject in school and is supported by a cadre of teachers with high aspirations. The nation's mathematics teachers, in fact, were the first to launch a campaign for national standards in education.

The post-Sputnik evolution of mathematics education is as international as mathematics itself. In the early years, the focus was clearly on accelerated learning of mathematics, the goal to move more students more rapidly into the higher reaches of mathematically based fields. Then the pendulum of mathematics education swung back from reform to restoration, from "new math" to "back to basics." Today the pendulum is once again swinging, this time wildly and unpredictably. In some school districts it moves in one direction, in others the opposite. Nations now regularly compare their students' performance in mathematics (and science), and the weak U.S. performance has led many states to impose, for the first time, a mathematics test as a requirement for high school graduation.

For the most part, this reform energy has been devoted to mathematics, not to numeracy. The mainstream mathematics curriculum moves students along the traditional progression from algebra to calculus, not from arithmetic to numeracy. No one has seriously tried to design a school curriculum that gives priority to quantitative literacy as described in the case statement. This is no doubt due in part to the weight of tradition. Mathematics, after all, has a much longer history in schools than does quantitative literacy. In official school tests, in college admissions, and thus in the public mind, it is not numeracy but mathematics that matters for students' futures.

The lack of widespread pressure for quantitative literacy may also be because numeracy is largely invisible to the public. True, the discipline of mathematics is not widely known either. But parents demand mathematics in school because they recognize that it remains today, as it was when they were students, a critical gatekeeper for future opportunities. The ubiquitous need for quantitative thinking is somewhat newer, so there is as yet little public recognition of its pervasive role in daily life and work.

Even the word "numeracy" is relatively new in the American lexicon. Indeed, the first widespread use of the term in the United States was somewhat indirect, being encapsulated in its negation: *Innumeracy*—John Allen Paulos' surprisingly popular outcry against quantitative illiteracy (Paulos, 1988). In other English-speaking nations, (e.g., England, Australia, South Africa) the word "numeracy" is widely used in commentary about education, most often in relation to the early years.

Indeed, governments in these countries have been explicitly pressing a numeracy agenda by urging educators to make school mathematics more socially useful.

In this country, arguments for numeracy come mostly from individuals, not governments. For example, to emphasize the need for effective communication of quantitative information, Yale political science professor Edward Tufte created an extraordinary three-volume work beginning with *The Visual Display of Quantitative Information* on the use and misuse of illustrations to convey numerically based ideas (Tufte, 1983, 1990, 1997). To make the case for the importance of quantitative literacy in contemporary life, financial consultant Peter Bernstein has argued in his best-selling monograph *Against the Gods* that most of modern civilization has been made possible by our ability to understand and control risk (Bernstein, 1996).

Various expressions of numeracy can be found in the bibliography at the end of this volume, as well as some recent expositions of mathematics. These sources not only illustrate the similarities and distinctions between mathematics and numeracy, but they also document the important need for both in students' education. Unfortunately, although every school attempts to deliver a strong mathematics program, vitally important aspects of numeracy such as communication of quantitative information and calibration of risks are all but invisible in standard school curricula.

Although quantitative literacy is a recent and still uncommon addition to the curriculum, its roots in data give it staying power. Mathematics thrived as a discipline and as a school subject because it was (and still is) the tool par excellence for comprehending ideas of the scientific age. Numeracy will thrive similarly because it is the natural tool for comprehending information in the computer age. As variables and equations created the mathematical language of science, so digital data are creating a new language of information technology. Numeracy embodies the capacity to communicate in this new language.

## Numeracy Initiatives

As masses of data began to impact ordinary people, as applications of elementary mathematics became pervasive in life and work, and as business and higher education began to question the effectiveness of traditional school mathematics, educators began to explore new approaches to improving students' quantitative experiences and capabilities. Perhaps because colleges operate with fewer encumbrances on curricular change than do secondary schools, most of these initiatives have taken place in postsecondary education.

Indeed, campus initiatives in the area of quantitative literacy are both numerous and diverse. The considerable variety of approaches attests to a healthy climate of experimentation but also to a surprising lack of consensus about either means or ends. In contrast to relatively stable subjects such as Freshman Composition, Introductory French, or Elementary Calculus, colleges seem to have no clear vision about the goals of quantitative literacy or the means by which these goals can most readily be achieved.

Examples of current projects and initiatives whose goals support quantitative literacy include:

*Chance*. A partnership of several institutions led by Dartmouth College, the Chance program develops courses that study important current news items whose understanding requires a knowledge of chance and risk. These courses are not designed to replace introductory courses in statistics; their goal, rather, is to encourage students to think more rationally about chance events and to make them more informed readers of the daily press. The program includes a professional development component for middle and high school teachers. [*Contact:* Peter Doyle; <doyle@math.dartmouth.edu>]

*Exploring Data in Hartford*. A mathematics proficiency requirement administered by the Aetna Mathematics Center at Trinity College, this program focuses on skills and concepts in four kinds of relationships (numerical, statistical, algebraic, and logical) that correspond to four proficiency courses: Contemporary Applications: Mathematics for the 21st Century, Cityscape: Analyzing Urban Data, Earth Algebra: Modeling Our Environment, and *Hartford Courant* Issues: Logic in the Media. All courses offered by the Mathematics Center are anchored in contexts using real data from the city of Hartford. [*Contact:* Judith F. Moran; <judith.moran@mail.cc.trincoll.edu>]

*Foundations of Scientific Inquiry*. A graduation requirement for all arts and science freshmen at New York University with three sequential components: Quantitative Reasoning (Understanding the Mathematical Patterns in Nature), Natural Science I (Introduction to the Physical Universe), and Natural Science II (Our Place in the Biological Realm). For each component students are offered a limited number of choices; for Quantitative Reasoning, the choices are mathematical patterns in nature, mathematical patterns in society, or mathematics and the computer. Quantitative Reasoning is designed to teach students to recognize mathematical patterns within verbally presented problems. The emphasis is neither on technical skills ("Kafkaesque algebraic manipulations") nor on memorization of facts, but on mathematics as the art of pattern recognition. [*Contact:* Fred Greenleaf; <fg3@scivis.nyu.edu>]

*Laboratories and Literacy:* With the support of grants from the National Science Foundation, the philosophy department at Trinity College (Hartford) has been collaborating with other departments to develop laboratories attached to philosophy courses. Jointly designed by philosophers, scientists, and mathematicians, these laboratories are modeled on those traditionally found in science departments. The laboratories develop specific problem-solving strategies central to mathematics and science, while philosophy classes examine the theoretical accounts and justifications of these strategies. [*Contact:* Helen Lang; <helen.lang@trincoll.edu>]

*Mathematics Across the Curriculum* (MAC). A National Science Foundation-initiated project at the University of Nevada, Reno, this program is designed to improve students' numeracy skills by helping faculty in different disciplines enhance the quantitative and mathematical content of their courses. One component of MAC is a series of "gateway" examinations that test the mathematical skills students will be required to have for success in various courses in different departments. [*Contact:* Jerry Johnson; <jerryj@unr.edu>]

*Mathematical Sciences and their Applications Throughout the Curriculum (MATC)*. As a sequel to its support of calculus reform, 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. MATC consortia were established at the University of

Pennsylvania, Rensselaer Polytechnic Institute, Dartmouth College, Indiana University, Oklahoma State University, State University of New York at Stony Brook, and the U.S. Military Academy at West Point. [*Information:* <www.matc.siam.org>]

*Quantitative Literacy for the Life Sciences*. An initiative of the University of Tennessee, Knoxville, this project is designed to enhance the quantitative components of undergraduate life science courses by illustrating the utility of quantitative methods across the full spectrum of the life sciences. Data-based quantitative examples for entry-level biology courses are used to illustrate key biological concepts. [*Contact:* Lou Gross; <gross@math.utk.edu>]

*Quantitative Reasoning Across the Curriculum*. A faculty development program at Hollins College focused on adapting ideas and materials from successful MATC programs at other institutions. To achieve this goal, Hollins brings project leaders to campus to lead interactive workshops for Hollins faculty who are adapting MATC ideas for quantitative reasoning courses across the curriculum. [*Contact:* Caren Diefenderfer; <cdiefend@hollins.edu>]

*Workshop Mathematics*. A project begun at Dickinson College, Workshop Mathematics developed three introductory-level courses (Quantitative Reasoning, Statistics, and Calculus with Review) primarily for at-risk students from underserved populations. These courses emphasize active learning, conceptual understanding, real-world applications, and use of technology. They broaden access to university-level mathematics by providing multiple entry points for students who have anxiety about studying mathematics or who do not respond to traditional modes of instruction. [*Contact:* Nancy Baxter Hastings; <baxter@dickinson.edu>]

## Next Steps

These projects represent only a tiny fraction of the many quantitative literacy activities already under way. They illustrate college and university efforts because this kind of initiative is more likely to be distinct and visible. Numeracy in secondary schools is harder to detect and describe, primarily because, as an interdisciplinary enterprise, it must live in an atmosphere dominated by pressure for disciplinary standards and, recently, by vigorous arguments about competing mathematics curricula. But here and there we can hear voices urging that school curricula heed the call of quantitative literacy.

To the individuals who helped create "The Case for Quantitative Literacy" we add the support (and occasional caution) of our several respondents. Although the engagement of these educators with numeracy is relatively new, their words and personal stories promise sustained attention. Taken as a whole, this book can clarify the character and importance of numeracy by situating it realistically in an interdisciplinary educational context, and by helping educational leaders understand how the newcomer numeracy relates to the old-timer mathematics.

Based on ideas advanced in this study, the National Council on Education and the Disciplines hopes to make quantitative literacy a priority for schools and colleges across the United States. By creating conversation, supporting initiatives, and encouraging communication among diverse numeracy efforts, NCED aims to shine a spotlight on the need for a different and more effective approach to teaching quantitative skills, an approach rooted in contexts across the curriculum rather than in abstractions that resonate only within mathematics class. In particular, NCED intends to support pilot projects and sites around the country, to sponsor a Web site to support teachers and inform the public, to issue occasional reports and analyses concerning the role of numeracy in contemporary society, and to work with professional organizations to improve articulation of expectations as students move from secondary to higher education.

Numeracy is not the same as mathematics, nor is it an alternative to mathematics. Rather, it is an equal and supporting partner in helping students learn to cope with the quantitative demands of modern society. Whereas mathematics is a well-established discipline, numeracy is necessarily interdisciplinary. Like writing, numeracy must permeate the curriculum. When it does, also like writing, it will enhance students' understanding of all subjects and their capacity to lead informed lives.

## REFERENCES

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