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# Mathematics and Numeracy: Two Literacies, One Language


## Lynn Arthur Steen, St. Olaf College, Northfield, MN


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From business decisions and personal finances to government policy and environmental monitoring, the need for school graduates to understand and be able to use quantitative thinking has never been greater. Daily headlines use quantitative measures to report on public opinion, financial markets, school test scores, risks of disease, consumer prices, and refugees from ethnic wars. Anyone who wishes can obtain data about clinical trials of new drugs, educational expenditures in local schools, projections of government budgets, and indicators of climate change.

This unprecedented access to numerical information will inevitably place more power in the hands of individuals and serve as a stimulus to democratic discourse and civic decision making. Without appropriate understanding, however, access to vast amounts of quantitative information can as easily mystify as enlighten. In an age dominated by numbers, individuals who lack the ability to think numerically can neither make wise decisions nor participate fully in civic life.

The source of all this data is, of course, the computer and its fruit, the Internet. Indeed, what the printing press did to increase the public's need for literacy, so the computer has done for numeracy. Since computers represent all information–words, graphics, music–as numbers, the ability to comprehend and transform quantitative data has become the new literacy of our age (Steen, 1997, 1998).

Considering the deluge of numbers and their importance in so many aspects of life, one would think that schools would focus as much on numeracy as on literacy, on equipping students to deal intelligently with quantitative as well as verbal information. But the evidence shows that they do not. Despite years of study and life experience in an environment immersed in quantitative data, many educated adults remain functionally innumerate.

Instead of focusing on numeracy, mathematics educators around the world have been pondering the implications of the Third International Mathematics and Science Study (TIMSS) and its follow-up (TIMSS-R). One intriguing finding--not definitive but certainly suggestive--is a weak inverse relation between students' performance in mathematics and their self-confidence and personal attitude towards the subject. In nations whose TIMSS scores are high (especially in East Asia), students are less likely to have favorable images of mathematics than in nations such as the United States whose TIMSS scores are low (Mullis *et al*., 2000).

This finding–indefinite though it may be–highlights an important educational issue concerning the new literacies required by our global technological society. To cope with the data needs of modern life, students need more than ever to become quantitatively literate, yet to meet the equally important demands of further education they also need to master the established discipline of mathematics. These are not the same goals. Even individuals who have studied calculus often 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. Although calculus and all that flows from it is a fundamental tool of modern science, it is not calculus but numeracy that is the key to understanding our data-drenched society.

Numeracy is not the same as mathematics, nor is it an alternative to mathematics. Mathematics is abstract and Platonic, offering absolute truths about relations among ideal objects. Numeracy is concrete and contextual, offering contingent solutions to problems about real situations. Whereas mathematics asks students to rise above context, quantitative literacy is anchored in the messy contexts of real life. Truly, today's students need both mathematics and numeracy.

### New Opportunities, New Uncertainties.

The age in which we live is witness to many major changes brought about by the rapid trend towards an interconnected, global society (Hean, 2000). Not only products and jobs but also diseases and terrorism spread quickly from one side of the world to another. The technological revolution that has created instantaneous worldwide communication and interdependence of national economies has also produced stunning advances in our understanding of nature, of society, and of life itself. In this way, technology has created both increased demand for higher education and an explosion in opportunities for life-long learning.

The relatively free international flow of people, ideas, and information has brought the world closer together–especially for students who have grown up knowing no other reality. School children can now engage in on-line discussions with their peers around the world. They can learn about each other's countries and cultures, hopes and dreams, concerns and fears. The opportunities and uncertainties of globalization, one fruit of advances in technology, requires that educators think anew about their priorities–not least about mathematics and numeracy.

Mathematics is one of the rare subjects that transcends time and culture. The Pythagorean theorem (named after a Greek sage despite being discovered independently in ancient China and probably elsewhere as well) is true in any culture and every century, and is studied wherever mathematics is taught. In a world of rapid change, mathematics is one thing that endures. Its heritage is a treasure we pass from generation to generation, a common store of wisdom whose usefulness takes on different manifestations in different cultures and settings.

Yet even as mathematics is rooted in timeless values and eternal truths, it continues to evolve. Three centuries ago Newton launched the scientific revolution by inventing a mathematics of motion. More recently, scholars in many fields have learned to measure, thus to master, chance and risk, thereby opening the way for enormous advances in both science and commerce (Bernstein, 1996).

Today's challenge to mathematics is not about motion or risk but about numbers. From household numeracy to scientific computation, more than anytime in recent memory the practice of mathematics requires proficiency and understanding of numbers. Whether accurate or not, students' perception that mathematics instruction is often anchored more in its pre-computer past than on the challenges of the modern internet society may help account for the paradox suggested by the TIMSS study–that even students who are good in mathematics often do not see it as something they desire for their own futures.

## Mathematics and Numeracy

In virtually every nation, school mathematics rests on a canon that emerged from nineteenth century European mathematics and spread via colonialism around the world. This curriculum begins with arithmetic in the elementary grades and moves through algebra, geometry, trigonometry, functions, and on into calculus and analysis by about the time students leave secondary school and enter tertiary education. Within the school system, this sequence of courses make a certain organizational sense: it moves from simple to advanced, builds systematically on concepts previously learned, and keeps pace (more or less) with students' abilities to deal with abstract relationships.

But outside of school these priorities make much less sense. Problems in which mathematical expertise may be helpful do not come with course labels attached. For example, an important U.S. government report on what work requires of schools (SCANS, 1991) embeds mathematical ideas--even mathematics itself--in entirely different categories. Some performance expectations that require mathematical competence are identified as "basic" skills (e.g., arithmetic, estimation, graphs and charts, logical thinking, understanding chance) and others as "thinking" skills (e.g., evaluating alternatives, making decisions, solving problems, reasoning, organizing, planning). Many fall under one or more advanced "competencies" involving *resources* (allocating time, money, material, and human resources), *information* (acquiring, evaluating, organizing, maintaining, interpreting, communicating, and processing), *systems* (understanding, monitoring, improving, and designing) and *technology* (selecting, applying, maintaining, and troubleshooting).

Algebra, geometry, trigonometry, and analysis sure sound different from resources, information, systems, and technology. These dramatically different perspectives on mathematics education–classical canon vs. modern employment--illustrate important differences between mathematics and numeracy. One conveys the power of abstraction, the other the power of practicality; one is organized by categories inherited from the past, the other focuses on the way knowledge is used in the information age; and one is encountered mostly in school, the other mostly in real life.

Of course, numeracy is of value not only for earning a living but also for leading an informed life (NCED, 2001). Numerate citizens will be better equipped to understand the many forces that shape their lives, including:

- how different voting procedures (e.g., runoff, approval, plurality, preferential) can influence the result of elections;
- that unusual events (such as cancer clusters) can easily occur by chance alone;
- the difference between rates and changes in rates, for example, a decline in prices as compared to a decline in the rate of growth of prices; and
- how small samples can accurately predict public opinion, how sampling errors can limit reliability, and how sampling bias can influence results.

These goals, too, appear quite different from those of traditional mathematics. They require greater understanding of chance and data, of percentages and risks. These quantitative aspects of citizenship are less those of algebra and geometry than of logical thinking, number sense, and data interpretation. They are, in short, less those of mathematics than of numeracy.

So the call for numeracy in schools is not a call for more mathematics, nor even for more applied (or applicable) mathematics. It is a call for a different and more meaningful pedagogy across the entire curriculum. Numbers arise everywhere, so the responsibility for fostering intelligent numeracy should spread broadly across the entire curriculum. Quantitative literacy must be regarded as much more than the responsibility of the mathematics classroom alone.

However, as the TIMSS results suggest, the mathematics classroom need to do its share lest students find mathematics of less and less relevance in this information age. For lasting learning to take place, mathematics must be seen by students as offering a context that is functional and relevant. Moreover, it must be about things that students recognize in the world around them. By relating mathematics to real contexts, teachers can help students make sense of why and how mathematics is used. Yet too often high school mathematics focuses on techniques needed for future courses that the majority of students will never take. The consequence–certainly in the United States, and perhaps in other nations as well– is a generation of students who feel alienated from mathematics and who therefore leave the educational system quantitatively illiterate.

What students need, and what society demands, is a breadth of quantitative skills rather different from the topics now emphasized on typical mathematics exams (including TIMSS). Being able to understand such everyday concepts as risk, annuities, spreadsheets, and the normal curve is every bit as important as being able to factor polynomials or define irrational numbers (Forman and Steen, 2000).

## School Mathematics

A recent report from the U. S. National Academy of Sciences urges schools to emphasize five elements of mathematical proficiency, namely conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Kilpatrick, 2001). Traditional curricula emphasize only one of these five: procedural fluency. A more robust curriculum designed to meet these broader goals would better ensure that students are prepared for the challenges they will face after school, both to use mathematical tools in daily life and to continue their study of mathematics and mathematically-based subjects.

A mathematics program designed for the information demands of the twenty-first century would look rather different from the nineteenth century inheritance that predominates now in most nations:

- Mathematics would be presented in contexts that make sense to the learner. For example, commonly used topics such as data, graphs, and logical analysis would be stressed as much as formulas and algorithms so that students see mathematics as a tool for everyday decisions.

- Interdisciplinary applications would show the relevance of mathematics in real-world situations and students would understand how mathematics is important in other subject areas and in future careers.

- All school subjects would reinforce the role of quantitative thinking as a tool for discovering and verifying insights that are relevant to other school subjects.

- By emphasizing problem solving and reasoning skills, mathematics instruction would better prepare students to deal with unfamiliar situations.

- By learning how to ask questions and demand clarity in explanations, students would develop autonomy in reasoning.

- Mathematical and quantitative skills would be linked to literacy in ways that enhance students' abilities to communicate about technical subjects.

Adding expectations of numeracy may seem like an excessive demand to make on a mathematics curriculum that most teachers would describe as already overcrowded. To this one might make two rejoinders. First, some of what makes the secondary school curriculum overcrowded is not truly necessary for all students at the point in their education when these topics are introduced. Not everything needs to be learned when it is first possible to learn it; some topics can and should be deferred until a later time when they are really necessary for the student's further education.

Second, topics that advance students' quantitative literacy are not so much additions to mathematics as they are applications and interpretations of mathematics. They are, to a great degree, mathematics set in context. As such, they provide ideal opportunities to review material whose long-term learning requires reinforcement in meaningful contexts. They also offer important opportunities to display the interconnectedness of mathematics, for example, by letting students see how probability and risk relate to ratios and linear equations, how the idea of area enables interpretation of the normal curve, and how errors of measurement limit the accuracy of calculations derived from these measurements.

Properly approached, quantitative literacy offers convincing demonstrations of the power of mathematical thinking. Without such demonstrations–or with demonstrations promised for future courses that many students never take–mathematics in school becomes a hollow regime that many students unfortunately reject. Students need both mathematics and numeracy. Each can reinforce the other, and each can provide effective opportunities for connections to other subjects.

Reaching consensus on more productive goals for school graduates will require the efforts of many people including school and university faculty (both in mathematics and in other subjects) together with employers and policy leaders. Quantitatively literate citizens need to know more than formulas and equations. They need to understand the meaning of numbers, to see the benefits of thinking quantitatively about commonplace issues, and to approach complex problems with confidence in the value of careful reasoning. Quantitative literacy empowers people by giving them tools to think for themselves, to ask intelligent questions of experts, and to confront authority confidently. These are the skills–of numeracy and mathematics–required to thrive in the modern world.

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