

Achieving Numeracy: The Challenge of Implementation

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“The Case for Quantitative Literacy” makes a convincing argument that quantitative literacy is necessary in the contemporary world. It suggests the need for a campaign to increase quantitative literacy. It makes some interesting points about the differences between quantitative literacy and mathematics. But it says little about how quantitative literacy is to be developed. There are some hints—“throughout the curriculum”—but few specifics. There are some warnings—more years of high school mathematics or more rigorous graduation standards will not work—but no prescriptions or recommendations.

In this response, I want to suggest some strategies for developing quantitative literacy. But first, we need to explore the differences between teaching quantitative literacy and teaching mathematics to understand why traditional schooling has not led to quantitative literacy. This analysis suggests an approach to teaching quantitative literacy that can generate recommendations for the next steps in the campaign.

Quantitative Literacy, Mathematics, and Statistics

The case statement makes two points about the difference between quantitative literacy and mathematical knowledge. The first is essentially a statistical one, namely, that more mathematics course work (calculus, trigonometry, etc.) in school has not led to an increase in quantitative literacy. A careful study likely would show some correlation between mathematical achievement and quantitative literacy because

some mathematical skills are a necessary part of quantitative literacy. But there are many examples of students with sophisticated mathematics course work in their backgrounds who possess minimal quantitative literacy, as well as many examples of students with remarkable levels of quantitative literacy but little formal mathematics. This suggests that trying to improve quantitative literacy by requiring more mathematics courses is at best inefficient.

The second point made in the case statement is that mathematics focuses on climbing the ladder of abstraction, while quantitative literacy clings to context. Mathematics asks students to rise above context, while quantitative literacy asks students to stay in context. Mathematics is about general principles that can be applied in a range of contexts; quantitative literacy is about seeing every context through a quantitative lens.

Learning mathematics generally involves two steps: learning mathematical principles and identifying mathematics in a context. Although students find the first step hard, they find the second step harder still. (Hence “word problems” evoke such panic.) School mathematics focuses almost exclusively on the first step, however, while quantitative literacy hinges on the second. Thus, although it is possible to imagine an educational system in which more mathematics courses lead to an increase in quantitative literacy, we do not currently have such a system.

As the case statement points out, statistics is the quantitative tool most likely to be encountered by ordinary individuals, leading to the conclusion that statistics is closer to quantitative literacy than is traditional school mathematics. Both the American Statistical Association (ASA) and the National Council of Teachers of Mathematics (NCTM) have worked to include more exploratory data analysis in the school curriculum. The 1989 and 2000 NCTM standards envision the school curriculum as a bridge to statistics in the way that it traditionally has been a bridge to calculus. Thus it is reasonable to believe that curricula based on the NCTM standards are likely to be better promoters of quantitative literacy.

Teaching in Context

If quantitative literacy is the ability to identify quantitative relationships in a range of contexts, it must be taught in context. Thus, quantitative lit-

eracy is everyone's responsibility. There are opportunities to teach it throughout the curriculum; however, experience teaching applications of mathematics suggests that teaching in context may be difficult. Let us consider why this may be so.

Teachers of mathematics and science often complain that students have difficulty applying the mathematics they have learned in another context. Part of the reason lies in the way that subjects are taught—separate from one another. But part of the problem lies deeper. Recognizing mathematics in another field requires understanding the context. A student's ability to understand a context depends heavily on the relationship of that student to the field in question. For example, nonscience students in calculus often dislike applications from physics because they do not understand that field. On the other hand, the same students may easily grasp applications from the life sciences and economics. Experienced teachers are aware of this phenomenon and often tailor their examples to the class.

Some years ago I did an experiment to illustrate the effect of context on students at the algebra-trigonometry level. I created two sets of mathematically identical problems in two different contexts, one everyday (e.g., the distance to grandma's home) and one scientific (e.g., the distance between atoms). No scientific knowledge was necessary to do the problems and they were not complicated. For example, one problem involved using the Pythagorean Theorem to find the third side of a right triangle. Students first did the everyday problems and then the scientific set. As they worked, they recorded all their thoughts on audiotape.

The results were not surprising, although their vividness was stunning. As expected, students did not realize that the two sets of problems were fundamentally the same. In numerous instances, a student could do a problem on the first set but not the corresponding problem on the second set. What was unexpected was the vehemence with which the students reacted to the scientific context. The tapes provided an opportunity to observe the mechanism by which the context became a barrier. Students went off on extended tangents (about how much they hated chemistry, for example) that completely distracted them from focusing on the problem. They literally wore themselves out by unnecessary efforts—sometimes 20 minutes in length—that had nothing to do with the problem, and then gave up. And this was on problems that they had essentially already solved on the previous set.

On another occasion, I observed a group of students making heavy weather of their homework on the blackboard because it used the cumbersome and unfamiliar symbols “fish” and “fish-on-nose.”* They too would have had a much easier time if the context—in this case the letters—had been familiar.

Students’ mathematical common sense and ability to apply their knowledge are clearly fragile. They easily evaporate in an unfamiliar context. They appear to be more fragile than students’ knowledge of mathematical algorithms. In my opinion, the observation in the case statement that “this inextricable link to reality makes quantitative reasoning every bit as challenging and rigorous as mathematical reasoning” significantly understates the difficulty many students have with quantitative reasoning. Students are not quantitatively literate both because quantitative literacy is not widely taught and because they find it hard. Thus, achieving quantitative literacy is an enormous challenge.

The Role of Insight

The reason that quantitative literacy is hard to learn and hard to teach is that it involves insight as well as algorithms. Some algorithms are of course necessary—it is difficult to do much analysis without knowing arithmetic, for example. But algorithms are not enough; insight is necessary as well.

Insight connotes an understanding of quantitative relationships and the ability to identify those relationships in an unfamiliar context. For example, a caller to *Talk of the Nation* (PBS, 2000) demonstrated insight when he pointed out that a tax of £8 out of £10 spent on gas is a 400% tax, not the 80% tax that the British government claimed (BBC, 2000). He saw the relationship between £8 and £10 and he saw the comparison to U.S. sales tax. I discussed this example later with a group of students who could all divide 8 by 10 and 8 by 2, but who could not see where the caller got 400% and 80%. These students knew algorithms, but were lacking in insight.

Acquiring insight is difficult. It involves reflection, judgment, and above all, experience. School curricula seldom emphasize insight as an

*Better known as α and γ .

explicit goal. If asked, most teachers would probably say that insight, if it occurs at all, develops as a by-product of learning mathematical principles. Although many modern curricula do attempt to build insight, there is still no commonly accepted method for doing so. The Third International Mathematics and Science Study (TIMSS) described the curriculum in the United States as “a mile wide, an inch deep” (U.S. National Research Center, 1996). These analysts hope that fewer topics and greater depth will lead to more insight.

But isn't insight required in mathematics? Indeed it is. In fact, insight is frequently what distinguishes a good mathematician from a poor one. But traditionally, the distinction between students with and without insight becomes vital only after calculus. At that point the division between the “haves” and the “have nots” often occurs by natural selection—those who do not have insight drop out of mathematics—rather than by teaching insight. Thus, at the school level, there is no preexisting channel to which we can easily assign the task of teaching insight. A new mechanism is needed. To be effective, the responsibility must be shared by many disciplines.

Quantitative Methods Throughout the Curriculum

My own students describe any shared teaching effort (such as quantitative literacy across the curriculum) as “a conspiracy.” A partnership among departments is apparently uncommon enough to look like a conspiracy. A good-natured conspiracy is exactly what we need, however. It is telling that students find it surprising when one field reflects what is being done in another, or when the same ideas come up in several courses. When quantitative literacy is the norm, this will no longer be surprising.

Quantitative literacy is achieved when students readily use quantitative tools to analyze a wide variety of phenomena. This requires constant practice. It also requires seeing such behavior as commonplace. This will not happen unless teachers model it. Verbal literacy became universal when it was perceived to be essential; quantitative literacy will be the same. No matter what we say or what curriculum we teach, students will remain unconvinced of the need for quantitative literacy if they do not perceive their teachers as being quantitatively literate. Even if their teachers are quantitatively literate, we still have an uphill battle because there

are many successful citizens who are not; however, ensuring that quantitative literacy permeates the school curriculum is an essential first step.

How do we arrange an infusion of quantitative literacy into the curriculum? Teachers will not simply relinquish time from their own courses; everyone considers his or her field to have been shortchanged already. It cannot be done at the high school level without the involvement of colleges and universities; high schools will not recognize its importance if colleges and universities do not model it. Thus, we need an interdisciplinary partnership that involves high schools, colleges, and universities. Such a partnership must have the backing of business and government, but it cannot be restricted to these communities.

Teachers in this partnership will be asked to take every possible opportunity to encourage students to look at course material through a quantitative lens. Unless they are mathematics teachers, however, it does not mean teaching the quantitative methods themselves. It means teaching students how to identify a quantitative structure and demonstrating the usefulness of a quantitative argument. For mathematics teachers, it means giving more time, perhaps equal time, to developing students' insight in recognizing mathematical ideas in context. For all teachers, it means taking part in an ongoing interdisciplinary dialogue. Such a partnership can lead to a college admission process that rewards quantitative literacy, high-stakes tests that reflect quantitative literacy, and college and high school courses that make frequent and substantial use of quantitative arguments.

Major change does not happen in this country without public conviction that change is necessary. With inspired leadership, a broad-based partnership of policymakers and educators has the potential to convince the public of the importance of quantitative literacy. This is a monumental but vital task.

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