Reaching for Quantitative Literacy

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The Focus Group on Quantitative Literacy addressed three key issues—why, what, and how. A lengthy introduction written by Donald Bushaw provides a response to the first question. The report of the Focus Group itself is devoted to a discussion of "what" and "how," based on experiences from many different institutions. Appendices provide information on research, commentary on course materials, and extracts from the Focus Group e-mail conversation.

Introduction: Why Quantitative Literacy?

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There seems to be wide agreement that a well-educated citizen should have some significant proficiency in mathematical thinking and in the most useful elementary techniques that go with it. In western civilization, the idea goes back at least to classical times, when four (the "quadrivium") of the seven liberal arts considered essential for the education of a free citizen were essentially mathematical. The role of mathematics was enlarged by the Enlightenment, by the Industrial Revolution, and by many events in modern science, technology, business, and the rapid intellectual evolution of humanity generally.

In recent years, amidst intense scrutiny and sometimes harsh criticism of the whole educational system in the United States, one group after another has expressed itself on the point. A representative statement (here considerably abbreviated) appears in the influential report *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Academy Press, 1989, pp. 7–8):

> To function in today's society, mathematical literacy—what the British call "numeracy"—is as essential as verbal literacy ... Numeracy requires more than just familiarity with numbers. To cope confidently with the demands of today's society, one must be able to grasp the implications of many mathematical concepts—for example, change, logic, and graphs—that permeate daily news and routine decisions ... Functional literacy in all of its manifestations—mathematical, scientific, and cultural—provides a common fabric of communication indispensable for modern civilized society. Mathematical literacy is especially crucial because mathematics is the language of science and technology ...

An emphasis on the expanding importance of general education in mathematics beyond high school was made over twenty years earlier, in the COSRIMS report *The Mathematical Sciences: A Report* (1968), p. 56:

> The impact of science and technology has become so significant in our daily life that the well-educated citizen requires a background in the liberal sciences as well as the liberal arts. It has long been recognized that mathematical literacy is an important goal of all liberal education. But in current education this training often stops at the secondary-school level. With the increasing quantification of many of the newer sciences, the impact of high-speed computers, and the general expansion of the language of mathematics, it becomes increasingly important for the college graduate to have some post-secondary training in mathematics ...

Or consider the following words from *The Mathematics Report Card: Are We Measuring Up?* (Educational Testing Service, 1988, p. 9):

> Looking toward the year 2000, the fastest-growing occupations require employees to have much higher math, language, and reasoning capabilities than do current occupations. Too many students leave high school without the mathematical understanding that will allow them to participate fully as workers and citizens in contemporary society.

Those who have been pleading for more nearly universal quantitative or mathematical literacy have not all been mathematicians, by any means. Consider the words from *50 Hours: A Core Curriculum for College Students* (National Endowment for the Humanities, 1989, p. 35):

> To participate rationally in a world where discussions about everything from finance to the environment, from personal health to politics, are increasingly informed by mathematics, one must understand mathematical methods and concepts, their assumptions and implications.

These statements and many others like them add up to an interesting challenge, and since about half of American colleges and universities have no general mathematics requirement for graduation, the challenge is clearly not being met.

There have been encouraging signs of improvement in recent years, but optimism can be premature. As these words are being written, it was just announced by The College Board that the average quantitative score on the SAT has taken another downward turn, after more than a decade without any decrease.

We have been speaking of *mathematical* attainments. The term "quantitative literacy" has so far appeared only in the title. Whether there is a real difference between "quantitative literacy" and "some significant proficiency in mathematical thinking and in the most useful elementary techniques that go with it" is a matter of debate. Sometimes the term "quantitative literacy" is a virtual euphemism for some level, usually ill-defined, of accomplishment in mathematics. (How unfortunate that some people should consider it expedient to use a euphemism for "mathematics"!) At other times "quantitative literacy" is used much more broadly, to include logic, linguistics, and other subjects that have at least a relatively formal character, even if they are seldom or ever taught in mathematics departments.

Here we shall adopt the point of view that "quantitative literacy" primarily concerns mathematics, broadly understood. It is not an entirely fortunate term. For one thing, much of modern mathematics, even at elementary levels, is not distinctively quantitative; for another, "literacy" suggests both facility with *letters* and a possibly very low level of accomplishment. The term "numeracy" is shorter, at least. Most, if not all, of what will be said here will apply whichever reasonable interpretation of the term "quantitative literacy" is adopted.

It may be useful to enumerate some of the principal reasons for expecting quantitative literacy of educated people. The list that follows is surely not complete, and the items in it are not independent; but it directs attention to some of the major areas in the broad range of "Why study mathematics?"

- Mathematical thinking and skills are of great value in *everyday life*. "Other things being equal, a person who has studied mathematics should be able to live more intelligently than one who has not. And, up to a point at least, the more mathematics studied,

the more intelligent the life should be" (NCTM, *A Sourcebook of Applications of School Mathematics*, 1980, Preface).

- One of the classic reasons for studying mathematics is that it strengthens *general reasoning powers*, for instance by developing problem-solving skills. While the research literature is ambiguous on this point, many thoughtful people are convinced that it is true in some sense.
- Quantitative literacy at varying levels is clearly needed in *preparation for further study* in many academic and professional fields. It is reliably estimated that the majority of undergraduates would be required to take a course or courses in the mathematical sciences for this purpose even in the absence of a general graduation requirement of this kind.
- Increasing amounts of mathematics are needed in an increasing number of *careers*. ... "More and more jobs—especially those involving the use of computers—require the capability to employ sophisticated quantitative skills. Although a working knowledge of arithmetic may have sufficed for jobs of the past, it is clearly not enough for today, for the next decade, or for the next century" (*Moving Beyond Myths: Revitalizing Undergraduate Mathematics* (National Academy Press, 1991, p. 11). And students, even college seniors, often do not know what careers they will enter, or where their career paths will lead them. A quantitative literacy requirement helps to hold some doors open.
- Many adults, and especially college graduates, are very likely to assume positions in their communities and in professional organizations where quantitative literacy (e.g., the ability to deal intelligently with statistics) will come into play and may even be essential for effectiveness. A quantitative literacy requirement can thus be expected to enhance the quality of *citizens*.
- Anyone who does not have a mature appreciation of mathematics misses out on *one of the finest and most important accomplishments of the human race*. A quantitative literacy requirement, sensibly defined, will contribute to the spread of that appreciation.
- Society can ill afford to under-develop *latent mathematical talent*. For many students the activities leading to satisfaction of a quantitative literacy requirement can be revelatory, inspiring them to consider for themselves careers in mathematics or mathematics-related fields.
- The fear of mathematics that is often called *math anxiety* or *mathophobia*, besides stunting the cognitive development of those who suffer from it, tends to communicate itself from one generation to the next, in the home, and elsewhere. It is usually learned, not in-born, and a quantitative literacy course or courses, if competently and compassionately taught, can be powerfully therapeutic against it. (Certain learning disabilities do seriously impede the learning of mathematics, but the number of people affected by these disabilities is small. Reasonable accommodations, for legal as well as humanitarian reasons, should be made for such students.)

Even if, as many thoughtful people believe, the educational process that finally produces college graduates should be regarded as seamless, practical considerations require that some line should be drawn between the pre-college part and the college part, or in other words between the secondary part and the tertiary part. The present report is sponsored by the Mathematical Association of America, which by its charter is concerned with "collegiate

mathematics," so is concerned mainly with the college part.

The term "remedial" (or "developmental"), as applied to a college mathematics course, has a definite meaning only where there is a clear understanding of where pre-college mathematics leaves off and collegiate mathematics begins. There are various opinions about where this line may be. However "remedial" is defined, the volume of remedial instruction to college students has certainly increased in the past several decades. According to *A Challenge of Numbers: People in the Mathematical Sciences* by Bernard L. Madison and Therese A. Hart (National Academy Press, 1990, p. 29):

> In fall 1970, college enrollments in remedial courses constituted 33% of the mathematical sciences enrollments in two-year colleges and by 1985 had increased to 47%. In four-year colleges and universities, remedial enrollments constituted 9% of the mathematical sciences enrollments in 1970 and had increased to 15% by 1985.

In spite of the volume of resources being poured into the teaching of such courses, there is widespread skepticism, backed up by some empirical studies, about their effectiveness, especially in preparing students for genuinely college-level mathematics courses. One should expect more from a quantitative literacy program for undergraduates.

But *is* there an intrinsically "college" part for all students? If agreement can be reached on what "mathematical methods and concepts, their assumptions and implications" every college graduate should understand, does it really matter whether that understanding is acquired before or after matriculation in a college or university? Is it not imaginable that, for example, the goals set for secondary mathematics in the NCTM *Curriculum and Evaluation Standards in School Mathematics* (1989) define an acceptable concept of quantitative literacy? And if so, and if the *Standards* are widely adopted, will there be anything left for the colleges and universities to do in this area beyond supplying suitable remedial experiences for those students who slip through the cracks? To put the matter another way, is it not imaginable that any quantitative literacy appropriately required for a bachelor's degree should in fact be regarded as an appropriate requirement for admission to a college or university?

There are several very large "ifs" in the preceding paragraph. They relate to difficult questions of definition, curricular diversity and inertia, a great lack of homogeneity in the student population, and other inconveniences. A more important consideration, perhaps, relates to the nature of the post-secondary experience.

College students, on the average, are more mature, more experienced, and more thoughtful about their personal goals than they were before they became college students. One does not need to invoke William Perry's scheme to justify a belief that college students should be better able to acquire, and to acquire more deeply, quantitative literacy in any reasonable sense. Indeed, because of the pervasiveness of mathematical ideas in the careers that college graduates usually enter, they should be *expected* to have acquired them more thoroughly and meaningfully than if they had not gone to college.

These ruminations are leading relentlessly to the conclusion that it might be a mistake to speak of "quantitative literacy" as if it were a single, monolithic idea. Surely there are meaningful *degrees* of quantitative literacy, and perhaps it would be useful to identify some of them. Here, we speak of only one—the degree of quantitative literacy appropriately expected of all *college* graduates. As we have suggested, we do not believe that this is identical with

the degree of quantitative literacy appropriately expected of all *high school* graduates, even as implied in such a forward-looking statement as the NCTM *Standards*.

Thus we take the stance that, for many reasons, some significant level of quantitative literacy is desirable in all adults; that the amount appropriate for college graduates is greater than that to be expected at the time of graduation from high school; and that the difference is not merely a matter of "remediation."

Cultivation of quantitative literacy at any level is, of course, a matter of teaching and learning. And teaching and learning involve far more than mere identification and communication of appropriate content. There is ample evidence that the traditional "lecture-and-listen" mode of instruction, still probably far more the rule than the exception in American higher education, does not work as well as some other modes—certainly not as well as it should. Particularly for those students who are studying in the mathematical sciences not by their own choice, teaching and learning styles that include active involvement, cooperation, and the personal touch are much to be preferred over those that do not.

So while the emphasis in this report will be on what the elements of quantitative literacy are, we also implore those who are responsible for providing students with classes and other opportunities for developing quantitative literacy to give a great deal of attention to the form those opportunities should take and the manner in which they should be delivered.

What Is Quantitative Literacy?

The Focus Group on Quantitative Literacy was summoned to its conference tasks by words from the National Academy Press' publication *Everybody Counts* (1989):

> Functional literacy in all of its manifestations—verbal, mathematical, scientific, and cultural—provides a common fabric of communication indispensable for modern civilized society. Mathematical literacy is especially crucial because mathematics is the language of science and technology. Discussion of important health and environmental issues (acid rain, waste management, greenhouse effect) is impossible without using the language of mathematics; solutions to these problems will require a public consensus built on the social fabric of literacy.

The conference invitation noted that the issues of quantitative literacy are of critical importance for the lives of all of us, since they shape the future of our democracy as we would like to see it. We are confronted daily with conflicting quantitative information and need to be aware of both the power and limitations of mathematics.

Faced with these weighty statements, conference participants attempted to sift and sort their thoughts into coherent responses to questions posed by the conference moderator. The difficulty of the questions posed was readily acknowledged. One participant who promised a "good answer" soon observed, "The trouble is, I keep changing my answers every few days; this is a tough nut to crack!" Yet another said, "I really am overwhelmed by your questions."

Despite difficult questions, the group uncovered a number of factors that need to be addressed in a quest for quantitative literacy—some arising in a straightforward manner and others arising more subtly.

At first, conference participants struggled with a response to the question of determining the key issues in quantitative literacy for the next five years. The issues were expressed, in one participant's words, in a series of questions: