Reflections on Wingspread Workshop

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If King Henry the 8th had six wives, how many wives did King Henry the 4th have?
— Overheard at Wingspread

"Quantitatively oblivious" is how Rhodes Scholar and historian Robert Orrill describes the condition in which his extensive humanities education left him. It also describes roughly half the young adult population of the United States today—although for very different reasons. The experts from a wide variety of fields who gathered in June 2007 at the Wingspread retreat center in Racine, Wisconsin, agreed on little else but this: it is dangerous for democracy if most of its citizens are quantitatively oblivious.

In this brief reflection I call attention to a few of the dozens of issues, concerns, and suggestions that emerged at this workshop, many of which are elaborated and documented in the reminder of this volume. Two special issues dominated the discussions: the relative roles of mathematics vis a vis other disciplines in the development of numeracy, and the potential of teacher preparation as a tool for enhancing numeracy. The issues are subtle, as Orrill's own reflection attests.

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In addition to giving his own testimony on the relation of humanism and numeracy, Orrill cites evidence from leading twentieth century humanities scholars to suggest that “an aversion to numbers” is deeply rooted in humane studies. Much of this aversion grew out of unease at society’s increasing “trust in numbers,” to use historian Theodore Porter’s apt expression (Porter, 1995). As the standard of civil and political evidence transitioned throughout the twentieth century from the arts and humanities to the natural and social sciences, quantification increasingly replaced classical verities as the foundation of accepted truths. The pretense of objectivity in social measurements rankles humanists still. Echoes of opposition to quantification can be heard throughout higher education even today as faculty argue with administrators and politicians about means of assessing the outcomes of liberal education.

Humanists are not alone in their aversion to numbers. It may come as a surprise to some that many mathematicians have a similar temperament. Berkeley mathematician and educator Alan Schoenfeld called his mathematics education from grade school through Ph.D. “impoverished”: no authentic applications, no data other than artificial numbers, no communication other than formal proofs (Schoenfeld, 2001). Although some mathematicians do study numbers, most do not. Instead they employ abstractions in which only the properties of numbers, not the numbers themselves, matter.

My own experience is similar to Alan’s. I recall a graduate school class in which the professor in the course of a single hour ran through the entire Latin and Greek alphabets as well as the first few letters of the Hebrew alphabet, but the only numbers in sight were 0, 1, and π. In many years of teaching mathematics to undergraduates, including many future high school and college teachers of mathematics, numbers were rarely of central importance. Since the time of the Greeks, mathematics has been largely about definitions, theorems, and proofs, not numbers, contexts, or measurements. Our heritage is the same as the humanist’s, and our disposition is not so much different.

So why, you may wonder, did I become involved with the small band of rebels who have been agitating on behalf of quantitative literacy (QL)? In the early 1990s I was a member of the College Board’s advisory committee for mathematics, and for reasons such as those I just outlined we all were mostly oblivious to quantitative literacy. But then the College Board’s advisory committee for science began to worry about whether their exams demanded enough mathematical and quantitative acumen to meet the increasing demands for quantification in college science courses. So they asked the mathematics committee for advice on the nature and level of quantitative literacy that would be appropriate to include on the College Board’s various science tests.

This question caused some consternation among the mathematicians and mathematics educators on our committee, not least because our first approximation to an answer was mostly disjoint from the topics that we had been advocating be on the College Board's mathematics tests. We were confronted with a dilemma that is still unresolved and that could be heard in many discussions at the Wingspread workshop: Is QL part of mathematics or isn't it? If so, why isn't it taught and learned? If not, who should teach it?

The College Board's response was to publish a series of essays called *Why Numbers Count* (Steen, 1997) that offered a variety of professional views focused, at least indirectly, on the science committee's original question. The leader of this College Board effort was none other than Robert Orrill, no longer quantitatively oblivious. Subsequently, with support from the Pew Charitable Trusts and the Woodrow Wilson Foundation, Orrill led a project intended to make QL a focus of faculty debate on college campuses across the country. The Wingspread workshop is the latest in a series of meetings related to QL that in various ways spun off from these early initiatives.

Has anything changed?

Essays in the current volume—the anchors of the Wingspread workshop—are as diverse and contentious as any of their predecessors. One noticeable change is that QL explorers have moved beyond debates about the definition of QL, not because they reached consensus but because they recognize that development of QL programs is more important (and is also an effective way to clarify definitions). Another change, clearly evident at Wingspread, is that individuals with broader experiences are now awake to the importance of QL and to the potential for connecting to other educational frontiers such as collegiate assessment, general education, and interdisciplinary initiatives. At Wingspread, linkages with teacher education played a central role.

In writing about the licensure of teachers for QL, Frank Murray unwraps layers of formidable complexity in order to disarm anyone who may imagine or suggest simple solutions. Teachers of QL need an extraordinarily diverse set of attributes, including confidence to tackle uncharted quantitative topics, operational skill in mathematical procedures, ability to solve problems that require both deduction and estimation, and experience in contextualizing economic, political and social data. The traditional resource that provides subject knowledge for teachers is the undergraduate major. Yet we now know that even in well established fields such as mathematics, the traditional academic major does not induce in students the kind of deep understanding necessary for a teacher to respond productively to creative conjectures that students readily offer. For a new field like QL—if it even is a "field"—without a major, it appears as if one may need either a miracle or a revolution.

Murray suggests several potential revolutions, including an interdisciplinary major made up of minors from several fields; a major focused on the epistemology of different fields; a great books major centered on seminal texts (not textbooks!) in several fields; and a cognitive psychology major focused on how the mind matures in comprehending different kinds of knowledge. It will take years of trials to see how well any ideas such as these may do in developing for the kind of QL knowledge that teachers need to be ready with apt examples, useful analogies, and constructive questions.

The other traditional component of teacher preparation, typically more contentious, is the cluster of courses and experiences (practice teaching) that focus on pedagogy more than content. Murray recounts the appeal of naïve teaching, that is, the natural instinct that all people have to teach what they know to others, to justify restraints on this component of teacher education. Since QL has not ever been an organized discipline, and is often overlooked by subjects that are organized as disciplines, much of what people learn in this domain comes from such naïve sources. Evidence shows, however, that teachers operating in this instinctive mode (primarily showing and telling) tend to have low expectations for students of different backgrounds and are inattentive to higher order understanding of the kind characteristic of QL. Untrained teachers have great difficulty, for example, with recognizing the value of productive student efforts that nonetheless yield incorrect results.

For a variety of reasons, public pressure for more and better teachers coupled with skepticism about the education establishment has led to a multiplicity of approaches to teacher licensure. In this environment, Murray argues, the effort to increase the level of quantitative literacy in the schools will surely fail unless all aspects of licensure are addressed and coordinated, including clarity about the assessable features of numeracy, establishment of an appropriate undergraduate major, new requirements for the teaching license, redesign of license tests, recognition in accreditation and state approval standards, and incorporation in the state's curriculum assessments. Without these, Murray warns, "the policy levers provided by teacher education, licensing, credentialing, and accreditation are relatively powerless to provide a structure that will support QL."

Is there any hope?

Murray's analysis pretty much buries the option of QL as a thriving K–12 discipline. However, this may not matter much since most QL advocates have not sought to go down that road. The predominant recommendations for QL seem to be either cross-disciplinary (e.g., like writing across the curriculum) or sub-disciplinary (e.g., within mathematics, rather like statistics now often is). But Murray appears to say more, namely, that unless QL takes on all the trappings of a discipline—standards, majors, assessments, licensure—it cannot grow within the K–12 scene.

Others seem more hopeful. For instance, Shoenfield—having recovered from his "impoverished" mathematics education—now believes that QL and the contents of school mathematics should be "largely overlapping." Richard Scheaffer, former president of the American Statistical Association, is "convinced" that quantitative literacy has a rather large overlap with statistics education, especially as the latter is being defined and developed for the K–12 mathematics curriculum (see, for instance, www.amstat.org/education/gaise/). Henry Kepner, president-elect of the National Council of Teachers of Mathematics, reports that QL is largely consistent with current mathematics standards and curricula, largely because data analysis, statistics and probability "has entered the main stream" of school mathematics. Kepner notes, however, that QL depends far more on the processes of mathematics—reasoning, communication, representation, connections, and problem solving—than do typical mathematics standards (which focus on skills and content).

Physicist-turned-mathematics-educator Hugh Burkhardt argued similarly at Wingspread in his paper on QL for all. He sees QL as a "major justification" for the large slice of curriculum time given to mathematics and argues that QL can be a powerful learning aid for mathematical concepts, particularly for those who are not already high achievers. Moreover, he avers, teaching QL well is mathematically demanding, even for mathematics teachers; those less well-prepared "could not cope."

Following much the same line of thinking as Murray, Burkhardt notes further that it is extremely difficult to establish and sustain cross-curricular teaching. "If QL is not taught in mathematics, it will not happen." However, he warns against the common pro-QL argument made by some mathematics educators that for most students, thinking mathematically about problems from everyday life offers powerful support for sense-making in mathematics:

> However true, this is an extraordinarily inward-looking view. For me and, I believe, for most people, the *practical* utility of being able to *think mathematically about practical problems* is the prime motivation for studying mathematics; its inherent beauty and elegance are merely a welcome bonus (author's italics).

Regrettably, Burkardt continues, among teachers of mathematics, there is too-often an unfortunate correlation between "knowing more mathematics and having an inward-looking view of it."

In his paper on critical thinking about public issues, sociologist Joel Best makes a similar argument about inward-focused mathematics, but draws from this observation an opposite conclusion. According to Best, educators teach mathematics as a series of what he calls increasingly complicated "calculations," by which he means all of the methods (e.g., arithmetic, equations, deduction) by which mathematical problems "are framed and then solved."

> Because mathematics instruction is organized around principles of calculation, calls for quantitative literacy tend to assume that students are not sufficiently adept as calculators, and that they need to improve their calculating skills, that they either need to beef up their abilities to carry out more sophisticated calculations or that they need to become better at recognizing how to apply their abstract calculation skills to real-world situations.

This preoccupation with calculation is Best's explication of the inclination towards inwardness that worries Burkhardt. Whereas Burkhardt seeks to draw QL into mathematics to save it from its inward tendencies, Best argues that QL requires issues of "construction" that move well beyond the boundaries of mathematical calculations:

> Humans depend upon language to understand the world, and language is a social phenomenon. In this sense, all knowledge is socially constructed. … In particular, numbers are social constructions. Numbers do not exist in nature. Every number is a product of human activity: somebody had to do the calculations that produced that figure. Somebody had to decide what to count, and how to go about counting.

This is not a mundane observation, says Best, especially when numbers frame public issues. Understanding such figures requires far more than calculation (that is, mathematics). To be quantitatively literate, students need to appreciate the process of social construction. Needless to say, this is not a skill in which mathematics teachers are trained and few are good at it.

Several Wingspread participants (mostly non-mathematicians) appeared to share this sentiment. "Why associate QL with mathematics?" asked psychologist Neal Lutsky. "Mathematicians are least well prepared to deal with the meaning of socially constructed numbers, which is the essence of QL." Indeed, the much-heralded goal of teaching mathematics in context is by definition out of context when done in a mathematics class. It is also very difficult to do there since mathematics students come from all sorts of different contexts. Perhaps contextual teaching—the essence of QL—really belongs where the context is the primary subject being taught.

Assessment expert Richard Shavelson adds yet a further caution. One suggestion often heard at Wingspread (and earlier) is to add QL to teacher education programs. Shavelson warns that even if it could be achieved, this proposal does not get at the heart of the problem, in part because "K–12 teachers are not the cause of the problem." The proposal, he claims, ignores the current policy and social contexts of education in the U.S. The policy context is one of high stakes testing:

> This form of accountability drives what gets taught by teachers in the classrooms. Unless QL becomes a central focus of what is meant by mathematics achievement, and this is very unlikely, it will be put aside even if we accomplished our goals with teachers.

The social context, Shavelson continues, is one of a society that largely does not possess, foster, or support QL. Most U.S. adults are not quantitatively literate. Many believe that mathematical and quantitative abilities are determined by birth (some have the "right stuff" and others do not). Worse, recent developmental data cited by Shavelson suggests that resistance to scientific and quantitative reasoning will arise and persist in children when such reasoning leads to conclusions that clash with prior expectations or with views championed by trusted adults. Thus it is that society's aversion to things quantitative is transmitted from generation to generation.

All these strands, and more, lead Shavelson to suggest that the proper response to the crisis of QL is not a special focus on QL for prospective and practicing teachers, but a broad focus on QL for all students, especially at the introductory college level. This route, indirect rather than explicit, will perforce include future teachers. Moreover, aspects of embedded QL are included in one of the most promising new tools for assessing liberal education, namely the Collegiate Learning Assessment (see www.cae.org/content/pro_collegiate.htm).

Interestingly, Orrill makes a similar suggestion with regard to students and teachers of the humanities: instead of forcing on them what their culture has traditionally viewed as repugnant, proponents of QL should invite humanists to use their own texts as a foundation for revisiting their stance toward quantification:

> Humanists are more likely to enter the conversation—and remain involved—if they can begin on familiar ground. At the same time, this also would bring QL into contact with documents and texts about which it so far has had little to say. Here, then, might be found the makings of a genuine conversation.

As Orrill recognizes, no one can predict whether such a conversation would be a productive undertaking. Current circumstances, he believes, suggest that the time is right to try. "Many humanists now are calling for a thoroughgoing reconsideration of humanistic practice; this self-questioning could open new, if still untried, paths through the academic hedgerows."

But can we communicate?

A second major theme that emerged from many Wingspread discussions was the obvious observation that quantitative literacy is a type of literacy—or in modern jargon, communication. Indeed, "communicating effectively about quantitative topics" emerged as a high priority need from virtually every source that economist Corrine Taylor studied in her analysis of what the business world wants in the way of QL. These sources expressed other needs as well, foremost being the habit of guessing and checking for reasonableness, known informally as "thinking for oneself," and experience with messy "cases" requiring a decision rather than only textbook problems with specific correct solutions.

One might say that mathematics is to QL as template problem solving is to authentic decision making. In the former, textbook exercises provide exactly the information needed to solve the problem—no more and no less; in the latter, the relevant data are typically both incomplete and contradictory. Many school mathematics teachers, by their own testimony, decided to pursue mathematics because they like to follow rules, and are most comfortable with the precision and definitiveness of a good mathematics problem. To help their students become quantitatively *literate,* mathematics teachers will need to encourage argument and discussion, just like English and history teachers do. That's a tall order. But to the extent that it succeeds, it would also help students become better mathematicians.

Discussion and debate about messy cases would surely help develop the strong communication skills about quantitative issues that experts say are keys to success in the business world. According to Taylor's findings, businesses strongly believe that their success depends on individuals "who can communicate with others on a team about assumptions, techniques, results, and decisions." Retired General Electric engineer William Steenken affirmed the importance of these skills in engineering also. "It's not only differential equations, but the ability to talk precisely and clearly about their work."

Psychologist Lutsky makes a similar case in his paper "Arguing with Numbers." His foundation, however, is not the needs of business but of liberal education. Based on work he and his colleagues have done with students at Carleton college, Lutsky opines that "the construction, communication, and evaluation of arguments" is a fitting context for quantitative literacy. In many situations, quantitative reasoning is an essential ingredient in the "framing, articulation, testing, principled presentation, and public analysis of arguments." In even more instances, QL is supportive although not central in making or critiquing an argument. Thus QL becomes an imperative for liberal education, both in high schools and colleges.

Many have suggested that "writing across the curriculum" is an appropriate model for QL: it recognizes the multi-disciplinary character of QL, honors the contextual differences among disciplines, and is a practical way to enlist relatively large numbers of advocates from different departments. The success of writing across the curriculum is an inspiration to those who hope QL will follow in these footsteps. Indeed, the National Numeracy Network (see www.math.dartmouth.edu/~nnn) is loosely modeled after the National Writing Project, a nationwide system of local coalitions that has provided effective support for writing across the curriculum for over a quarter century. In 2008, the NNN launched a new electronic journal *Numeracy: Advancing Education in Quantitative Literacy* (see services.bepress.com/numeracy).

While not disputing the possibilities of QL across the curriculum, Lutsky adds a unique twist: instead of working across the whole curriculum, focus on the teaching of writing:

> Quantitative literacy can be usefully situated in the context of argument, in the presentation of statements supporting claims. In this sense, arguments are not only reasons to take one position or another on a contentious issue but address … claims about the nature of a phenomenon or the importance of a topic. Teaching students how to identify and find the constituent elements of an argument, how to organize arguments systematically, … how to present arguments clearly and meaningfully, … how to address their own arguments reflectively, and how to evaluate others' arguments are fundamental to education at all levels and in almost all disciplines.

By examining a wide variety of papers that college students wrote for courses across the curriculum, Lutsky and his colleagues discovered that a third of these papers failed to use quantitative reasoning when it should have been central to the analysis, and nearly nine in ten failed to use QL when it was peripheral but of potential benefit to the argument. Clearly, there is much potential for QL within courses that stress written (and oral) analyses.

Statistician Milo Schield puts his finger on one possible reason why so many students write papers absent potentially helpful quantitative reasoning: most do not know how to express simple quantitative ideas in clear English. Many will confuse, for example, the percentage of males who are smokers with the percentage of smokers who are male. In one study, 20% of college students were unable to read a 5th grade pie graph showing percentages of smokers divided by religion (protestant, catholic, other). Notwithstanding the ubiquity of tables and graphs in popular media such as *USA Today*, translating the meaning of numbers and percentages that appear in such tables into correct English is beyond the ability of all but a small minority of even college-educated adults. It seems plausible to infer from the widespread inability to express correctly the meaning of such numbers a corresponding inability to understand their meaning.

Schield's paper is one of two devoted to fractions, the tormentor of millions of school children (not to mention of educated adults). He focuses on the needs of the 40% of college students who major in non-quantitative subjects. These students, he notes, are more likely than their quantitatively-oriented classmates to become journalists, policy advocates, lawyers, opinion makers and political leaders, thereby influencing local and national policies. Schield advances the rather radical proposition that to improve quantitative literacy and attitudes towards mathematics, it makes sense to deemphasize fractions for these students and focus more on percentages and rates. He asks, pointedly, why should they be burdened with mastering the arithmetic of mixed fractions (1/3 + 2/7) when so many cannot even translate a simple proportion into clear English? Isn't it more important to emphasize understanding the multiple representations of fractions in tables, graphs, proportions, percentages, and ratios than to focus on manipulating numbers which for all too many students demonstrably convey no meaning?

Good questions, all. Applied mathematician Alan Tucker empathizes. Too many students, he notes, fall off the ladder of mathematical learning in the transition from whole number arithmetic to fractions. Like Schield, Tucker offers his own catalog of horrors, such as the fact that given a choice of 1, 2, 42, or 45 as approximate values of 19/20 + 23/25, a majority of U.S. eighth graders chose 42 or 45. These students, Tucker observes, "did not think of a fraction as a number."

Whereas Schield worries that students do not know what a fraction *means*, Tucker worries that that they do not know what it *is*. That distinction about summarizes the archetypal difference in approaches that distinguish social scientists from mathematicians. Students, of course, need to know both what a fraction is and what it means. For adults, it is probably more important that they remember what it means.

Tucker urges that children be introduced to fractions first via *unit fractions* such as ½, ⅓, and ¼. For young children, he says, unit fractions evolve naturally from counting numbers: if a pie is divided into equal fourths, the pieces when counted yield a total of 4. In this way, unit fractions can be thought of as a type of counting number known as *reciprocals*. They fit easily into the various counting activities in which young children engage as they learn about numbers.

Then at the earliest appropriate age, Tucker says, children should be told that a *fraction* is a "number that is an integer multiple of some unit fraction." For example, ¾ means 3 × ¼, where ¼ is a number with the property that four of them add up to 1 (a "unit" in mathematical jargon). Of course, in real elementary classrooms, these spare definitions would be supported by a variety of examples from everyday life such as telling time, making change, cooking, sharing portions, and measuring small quantities.

For mathematicians, the decision to define fractions in terms of unit fractions solves a major conceptual problem, namely, establishing that a fraction is a number. The logical chain from counting number to unit fraction to (ordinary) fraction satisfies the mathematician's sense of definitional clarity. Some children—not all, but an important cohort—will also appreciate this clarity. Others, at least, may find that it helps avoid unnecessary confusion.

Tucker identifies a second less obvious advantage of defining fractions this way: it makes clear that the numerator and the denominator of a fraction represent different things. Numerators are standard counting numbers, while denominators are a totally new quantity, namely, reciprocals. This distinction, the theory goes, will help students overcome the strongly held belief that numbers must be whole numbers, and that fractions are not numbers but rather just part of something.

A third advantage elucidated in Tucker's paper, is that unit fractions help clarify the distinction between fractions and division: a fraction is a number that may be the answer to a particular division task. Confusion arises because after the early grades, we use the fraction notation (¾) to mean both the number ¾ and the arithmetic problem 3 ÷ 4.

Finally, and perhaps most important for QL, unit fractions focus attention on the role of units (e.g., miles, feet, inches) as mediator between an abstract number (¾) and a real context (¾ mile), and on the way rates are used to convert from one type of unit to another. Changing from miles to feet is much like changing from thirds and fourths to twelfths when seeking a common denominator in order to add ⅓ + ¼.

Despite their vastly different approaches, Schield and Tucker share a common concern that current schooling is strikingly deficient in achieving a primary goal of middle school mathematics, namely to convey the interrelated meanings of fractions, percents, proportions, decimals, ratios, and rates. For several centuries many of these topics were collected under the "rule of three" (given any three numbers, find the fourth); until the beginning of the twentieth century, the rule of three (and some Euclid) was all the mathematics expected of students entering American colleges.

Kepner noted that one reason for the decline in comprehension of these topics by high school graduates in the last half century is that teachers taught them according to the different algorithms required for calculation rather than as different perspectives on a common topic. No wonder most adults do not recognize fractions, ratios, and percents as three representations of the same thing: even when well learned, they appear as they were taught: as three distinct notations, each with distinct rules for calculation. One can see from this tidbit of pedagogical history why the "calculation" perspective, as Best put it, is totally inadequate to meeting the interpretive needs cited by Taylor, Schield, and Tucker.

So what's next?

Although mathematics plays a central role in the relentless recent increase in student testing, no one ever seems to ask why. Parents and politicians take for granted that mathematics is essential for work, for college, and for informed living. Even the once-oblivious Orrill now argues that

> if individuals lack the ability to think numerically, they cannot participate fully in civic life, thereby bringing into question the very basis of government of, by, and for the people (Orrill, 2001).

Whereas humanists in the late 19th century warned against the idolatry of large numbers that politicians used to praise the ever-expanding American life, a century later we find numbers have penetrated every aspect of social, political, economic, and cultural life. Now not only our economy but also our democracy depends on numbers.

But is the numeracy we need to guard our democracy the mathematics found on required school tests? I think it is fair to say that virtually every Wingspread participant would answer this question in the negative, though not all for the same reason. Some would say the tests do not reflect good mathematics; others that good mathematics is not effective numeracy; still others that numeracy cannot be tested in this manner. But every participant would also recognize that teachers and students have little choice but to focus on the high-stakes tests as they are. This is what Shavelson calls the ignored policy context of education.

Fortunately, higher education has so far escaped the deluge of narrowly focused tests, and the assessment options currently being explored (e.g., CLA) are very compatible with the goals of quantitative literacy. Even though some might wish that students' QL needs would be met by their secondary education, it seems clear from the analyses at Wingspread that the most creative and effective forces for QL will be those in postsecondary education.

Higher education is in many ways exactly the right place for QL to develop and diversify. As a nation we are blessed with an extraordinary variety of institutions—public and private, large and small, two and four year, college and university—all of whom actively innovate in order to compete for students. Many very different QL projects are already underway in postsecondary institutions. I would anticipate that as ideas from Wingspread become known more widely, some of the issues debated there will take shape in the form of pilot programs on different campuses. The infrastructure to support this work is already in place—within mathematics, via the MAA's Special Interest Group for QL (see www.maa.org/sigmaa/ql), across disciplines via the National Numeracy Network, and on the web via the new electronic journal *Numeracy*.

Of course, higher education is not without its own impediments. Academic silos, entrenched curricula, state articulation agreements, academic guild requirements—not to mention recalcitrant tenured professors—will keep the campus QL rebels well occupied. They will not have the luxury of a "clean slate" as the earlier Wingspread meeting had hoped. But they now have momentum: energetic leaders, active programs, and budding professional associations.

Should QL be part of a college's mathematics requirement or organized across the curriculum with "Q" courses in many departments? Might it be integrated into Comp 101 as part of every freshman's initial exposure to college writing? Do students in non-quantitative tracks need QL, or do their current requirements suffice? What should be done for college students who do not know what fractions are or mean?… The list of questions is endless, more than enough to fill the agenda of the next numeracy workshop.

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