Preparing Students for the Business of the Real (and Highly Quantitative) World

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Could the half trillion dollar aggregate cost of the telecommunications crash of the 1990s and early 2000s have been mitigated had our nation's schools and colleges emphasized quantitative reasoning (applied math, logic, and statistics in context within a culture of spelling out and questioning assumptions) rather than "school mathematics" divorced from the real world?[1] Likely so. John Handley, telecommunications consultant and author of *Telebomb: The Truth Behind the $500-Billion Telecom Bust and What the Industry Must Do to Recover* describes myriad problems that precipitated the telecom crisis, beginning with false assumptions and faulty quantitative reasoning that resulted in tremendous overinvestment in communications networks. Explaining the "fundamental fallacy" Handley writes:

> To attract investors, new entrants [in the race to cover the US in fiber-optic cable] depended on a catch phrase that passed for fact at the time but has since been debunked. Beginning in 1997, various parties interested in seeing the Internet grow began repeatedly to drop the sound bite that "Internet traffic doubles every ninety days." Although

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> this was probably true during the early commercialization of the Internet in 1995 and 1996, it should have been obvious that growth on that scale could not be sustained. It is much easier to grow at a given percentage from a smaller base. It is easier to grow revenue from \$100 to \$200 than it is to grow from \$100,000,000 to \$200,000,000, for example. An additional \$100 is easier to find than \$100,000,000.[2]

Handley goes on to say that "the sound bite persisted at a time when most entrepreneurs were moving too fast in the Internet land grab to spend time *thinking for themselves*"[3] (emphasis mine). In today's highly quantitative world, we need citizens who can think critically about such issues. This paper asks: How can we best prepare today's students who may be the entrepreneurs of the future—whether on the scale of investing millions in telecommunications or, more likely, investing in their own small businesses—with the quantitative skills and habits of mind to routinely question such assumptions and "do the math"? How can high school and college curricula offer more authentic opportunities for students to apply quantitative reasoning (QR) in business and personal finance arenas that they will likely encounter upon graduation? And how can we provide better training for teachers so that they can guide students in combining the important business (and general critical thinking) skills of seeking out information, analyzing that information, making decisions, and communicating findings? Moreover, how do we create a society of people who routinely *think for themselves* and not follow the mob even when—especially when—the real world problems at hand are quantitative in nature?

What skills matter most?

Quantitative reasoning skills are required of today's citizens in so many aspects of everyday life, as is emphasized in *Mathematics and Democracy: The Case for Quantitative Literacy*.[4] This paper focuses on one specific area: business. What kinds of QR skills are most important in the business world? To answer this question we draw from multiple sources. First, we examine the mathematics content areas and QR skills emphasized on the aptitude test generally required of candidates for masters' of business administration (MBA) programs. Second, we explore other QR skills and learning approaches that business schools value at both the undergraduate and graduate school levels. Third, we examine the skills that business consulting firms screen for when interviewing job applicants. Next we consider the quantitative business skills required in planning, launching, managing, and closing a small business. Assisting with the explorations above are the insights of experts from business schools, consulting firms, and the Small Business Administration. We also gain insights from some leaders in the QR movement and from my own experiences as a strategic planning analyst and as a college instructor for economics and QR.

Lessons from the GMAT, business schools, and the CLA

The GMAT (Graduate Management Admission Test) is the test used by more than 1,500 business schools world-wide to assess the potential of applicants to MBA programs.[5] This aptitude test has three main sections: the analytical writing section, the verbal section, and the quantitative section.[6] The assessment's emphasis on communication skills—particularly the importance of writing clearly about analytical topics—is noteworthy. The quantitative section uses two types of multiple-choice questions: (1) "problem solving questions" that are designed to test basic mathematics skills, the understanding of basic concepts, and the ability to reason and solve quantitative problems; and (2) "data sufficiency questions" that require one to examine a question and two statements that contain additional information and determine whether there is sufficient information to answer the question posed.[7] While the multiple choice format of the quantitative section is understandably disappointing to advocates of open-ended, authentic QR problems (and yet is the norm for standardized tests),[8] it is the *mathematics content areas*, not the format, of this test section that is of most interest in understanding what is required of business school applicants. Also of interest are the combinations of skills required in addressing these questions.

Calculus is *not* a content area tested on this assessment; rather the GMAT's quantitative section assesses one's core skills in arithmetic, algebra, and basic geometry. Most questions deal with the commonly applied skills of using basic arithmetic operations; dealing with fractions, percents, and ratios; reading and interpreting graphs; measuring and comparing values, often with different units; and working with models of linear and exponential growth. The data sufficiency questions test one's ability to reason in addition to being able to apply the mathematics content areas above. These emphases make sense given the most common applications in the major business disciplines of accounting, finance, marketing, and management. Indeed, Richard Cleary, Professor of Mathematical Sciences at Bentley College, reports that while calculus is important in a few specialized areas such as risk management, actuarial science, and high-end finance, and is helpful in solving economic problems of constrained optimization, the great majority of business problems do not involve calculus or other high-level mathematics; rather, most business problems utilize the mathematics content areas tested on the GMAT as well as statistics.[9]

These are precisely the areas that QR proponents argue should be emphasized more in context at both the high school and college level if we are to create a quantitatively literate society able to handle the business of the real world.[10]

Beyond knowing how to apply mathematics to solve problems in context, Cleary (along with every other business or economics professor I know) ranks the ability to "guess and check" as a key QR skill, especially given the common use of technology. That is, before beginning quantitative business problem—even a narrowly defined calculation problem—one ought to have an idea of the right order of magnitude of the solution; if one cannot even make a guess, then how clearly can one understand the problem? And on the other side, once a solution is determined to a problem, one ought to be able to check that it is of a reasonable value.[11] We all know stories of students who have used a calculator to perform a computation, made some error in pushing buttons, and proceeded to report an answer that was clearly unreasonable – way off in order of magnitude. Teachers worried that "calculator dependency" kept students from actual *thinking*. Now, with bigger, more complex business problems (problems that still use core skills, but often with large numbers of observations or repeated steps for many years of analysis), students routinely use computers as tools in their problem solving, creating a concern over "computer dependency." As Cleary says, "It's easy to use a very powerful computer to get a very wrong answer."[12] While business students need to know how to perform calculations and complex analyses on computers, more than ever, they need to apply core quantitative skills to estimate and check for the reasonableness of answers.

Many other quantitative reasoning skills are needed to address authentic business problems that are, by nature, complex. Real world problems require devising an overarching plan for addressing the problem, finding information, assessing the quality of the information, making reasonable assumptions where information is not readily available, determining the best analytical approach, using technology when needed to perform the appropriate analyses, checking the reasonableness of calculated values, interpreting the meaning of calculated values, evaluating the decisions that those values lead to, and communicating the findings clearly, both orally and in writing. Business applications naturally integrate these many critical thinking skills that are too often taught in isolation in most K–12 schools and even in colleges. Unfortunately, in mathematics courses, students are rarely asked to find data or make assumptions; textbook problems typically provide all the required information and one simply needs to use the technique *du jour* to combine the information given in order to produce the desired result. (Today is Tuesday, linear growth day, so I must be able to fit this problem into the formula $y = mx + b$.) Also, because mathematics courses tend to focus on the techniques used in making calculations, students are rarely asked to communicate their finding using complete sentences. At the same time, writing courses typically focus on literary analysis or on other topics in the humanities; most high school students (and even college students) get very little practice writing about quantitative topics outside of crafting science laboratory reports.

High schools and colleges would likely benefit from adopting the integrated learning approaches used by undergraduate business programs and graduate schools of business in honing students' quantitative skills and, more generally, their critical thinking skills. In particular, the case method, used extensively in business programs around the world, is an effective approach.[13] A case presents a "detailed account of a real-life business situation, describing the dilemma of the 'protagonist'—a real person with a real job who is confronted with a real problem."[14] Students are presented the situation "exactly as the protagonist saw it, including ambiguous evidence, shifting variables, imperfect knowledge, no obvious right answers, and a ticking clock that impatiently demands action."[15] In the case method, students are not merely charged with making a *calculation*; rather, they must make a *decision*: What should the protagonist do? With this approach, students cannot help but be motivated and engaged. Case studies are so much more interesting and relevant than the typical artificial little questions in most mathematics text books. At the same time they challenge students to apply what Benjamin Bloom calls "higher order thinking" skills, going beyond questions requiring *knowledge*, *comprehension*, and *application*, to those involving *analysis*, *synthesis*, and *evaluation*.[16] Because case studies require students to evaluate quantitative evidence, determine reasonable analytical approaches, perform complex calculations, make decisions, and communicate not only the results but also the process, they provide the opportunity for students to sharpen all their QR skills.

A relatively new assessment system (piloted in 2002) takes just such a holistic approach, using open-ended "performance tasks," among other instruments, to measure improvements in college students' critical thinking, analytical reasoning, problem solving, and writing.[17] The Collegiate Learning Assessment (CLA), developed by the Council for Aid to Education in conjunction with the RAND Corporation, provides formative assessments of the value-added at colleges and universities by testing a sample of each participating institution's first year students in the fall and seniors in the spring. The performance tasks completed by the students are authentic activities "such as preparing a memo or policy recommendation by using a series of documents that must be reviewed and evaluated" allowing the students to demonstrate their "ability to interpret, analyze, and synthesize information." The CLA tasks I have seen are excellent; I hope that these types of open-ended, holistic problems are used more often to assess QR skills in business and in other disciplines as well.

Lessons from consulting firms

Firms that help businesses of varying sizes grow and prosper by providing management and/or technology consulting hire both individuals with higher degrees such as MBAs and graduates straight out of college. College graduates may have bachelors' degrees in arts or sciences but need to exhibit strong critical thinking, analytical, writing, and oral communication skills, says Beth Reiland, Chief Personnel Officer for the Exeter Group.[18] Reiland argues that the kinds of core skills tested on the GMAT quantitative section are the necessary building blocks of problem-solving, but emphasizes that having these analytical skills is not sufficient. Workplaces need individuals who can *communicate effectively* with each other about quantitative issues. "In the business consulting environment, we come up with better solutions using collaborative thinking processes," Reiland explains. "Solutions to complex problems are improved by working in cooperative groups: sharing assumptions and information, thinking aloud about approaches, and testing ideas with others." Therefore, Reiland continues, educators need to "devote energies to developing a clear language for communicating about quantitative topics."[19]

The importance of being able to communicate effectively about quantitative topics is reflected in the personal interview process used by consulting firms today. In the old days, interviews were essentially chats about one's education and interests; today they are challenging tests of the applicant's analytical and communications skills. In *How Would You Move Mount Fuji? Microsoft's Cult of the Puzzle: How the World's Smartest Companies Select the Most Creative Thinkers*, author William Poundstone describes how loosely-defined questions and Fermi puzzles are being used in interviews of not only technology firms such as Microsoft, but also Fortune 500 companies, "law firms, banks, consulting firms, and the insurance industry; airlines, media, advertising, and even the armed forces."[20] Below are a few examples of these puzzles from Poundstone's book:

- How many gas stations are there in the United States?
- How long would it take to move Mount Fuji?
- Suppose you're hired as an IRS agent. Your first job is to find out whether a nanny agency is cheating on its taxes. How would you do it?[21]

Depending on the situation, the interviewer may expect the interviewee to be able to solve the problem without additional information, or he or she may be willing to provide more information when asked for specific details. For many of these puzzles the emphasis is on making reasonable assumptions, coming up with an approach for solving the problem, and applying QR skills to come up with what my boss used to call a "back-of-the-envelope" solution. Calculators are verboten. Typically the interviewer explains that he or she would like a "running monologue" (if not a dialogue) to show the interviewee's thought process.[22] The interviewer assesses not only the interviewee's overarching approach, logic, and mathematics skills, but also his or her exposition. Consulting firms do not want to hire mathematics geniuses who can solve problems on paper but cannot talk about the approaches and solutions with others. They want individuals who can communicate with others on a team about assumptions, techniques, results, and decisions.

In addition to, or instead of, presenting loosely-defined puzzles, many management consulting firms present interviewees with short cases similar to those used in MBA programs. The interviewer presents the basic challenge faced by the protagonist, along with selected evidence. Interviewees need to process the relevant information and ask specific questions to obtain additional data that they think would be relevant to the problem at hand. Case studies are definitely dialogues. McKinsey & Company, a premier global management consulting firm, tells applicants: "During the case study we look for evidence of your ability on a number of different dimensions – logical reasoning, creativity, quantitative skills, business judgment (not business knowledge), pragmatism, and an ability to structure problem solving."[23] Again, in showcasing these abilities, the interviewee needs not only the logic and mathematics skills but also strong communication skills about quantitative topics.

Lessons from small businesses

While graduates of top MBA programs and employees of management consulting firms are known for working with Fortune 500 firms and other large and medium-sized corporations, 98% of businesses are categorized as "small businesses" with fewer than 100 employees and 99.7% are businesses with fewer than 500 employees.[24] These firms include "mom and pop" convenience stores, greengrocers, florists, drycleaners, small retail shops, restaurants, neighborhood fitness centers, landscapers, professionals such as dentists, lawyers, and accountants who "hang out their shingles," Web site development companies and other small providers of computer services, small manufacturing and construction companies, and many, many other types of businesses. The Small Business Administration (SBA), the US governmental agency that assists small businesses, provides resources including a Web-based planner to help small business owners plan, start, and manage a business, and when the time comes, sell the business.[25] The "Small Business Planner" provides information and resources on each of the following topics:[26]

Plan your business	Start your business	Manage your business	Getting out
Get ready	Find a mentor	Lead	Plan your exit
Write a business plan	Finance start-up	Make decisions	Sell your business
	Buy a business	Manage employees	Transfer ownership
	Buy a franchise	Market and price	Liquidate assets
	Name your business	Market and sell	File bankruptcy
	Choose a structure	Understand fair practices	Close officially
	Protect your ideas	Pay taxes	
	Get licenses, permits	Get insurance	
	Pick a location	Handle legal concerns	
	Lease equipment	Forecast	
		Advocate, stay informed	
		Use technology	
		Finance growth	

Examining these business decisions, we note that about half of them are quantitative in nature. More detailed questions for these topics would include: What combination of drawing from savings and taking out loans makes the most sense in financing my start-up? Should I buy or lease my equipment? If I take out a start-up loan or if I lease equipment, which of the various timelines offered is best for my particular circumstances? How much insurance do I need to get and from whom will I get the best coverage for the price? What prices should I charge for my products and services to cover my costs, provide a suitable rate of return, and remain competitive in the marketplace? What do I predict sales will be one year from now? In considering the mathematics skills required in addressing these types of questions, we note again that calculus is not essential; rather, arithmetic, algebra, and statistics are the core mathematics content areas.

Of course, the real trick is not simply being able to solve an algebraic equation, but being able to translate the language of the real world business question into the relevant mathematics problem, finding the information needed to answer that problem, and understanding what the mathematical solution implies for the best decision. Small business owners need to be able to communicate with bankers, lawyers, tax consultants, their suppliers, their customers, their employees, and others about these many quantitative issues. Robert Berney, retired chief economist for the SBA, stresses that the K–12 foundations of clear communications in English (reading and writing) are every bit as essential as basic mathematics (arithmetic) in preparing students for the world of business.[27] Those famous "three Rs" are still the key to a solid base of critical thinking skills.

Lessons from QR teachers

William Briggs, co-author of *Using and Understanding Mathematics: A Quantitative Reasoning Approach* and Professor of Mathematics at the University of Colorado–Denver, gives an example of a very short, basic business problem he assigns his QR students. The problem is taken directly from a newspaper article: The CEO of a struggling airline plans to take an 85% salary cut. The cut would reduce his salary to $500,000 per year. What was his salary before the cut?[28] Of course, the problem is a simple algebra problem at its core, but the algebra itself is not the hard part for most students. Once the problem is in the form $x - 0.85x = \$500{,}000$, students find it pretty easy to solve for x. The real challenge for Brigg's college students is in translating the words into the algebraic expression. Students need more opportunities to work with practical word problems and they need practice developing the critical thinking strategies to do that translation from words into formulas. Briggs helps his college students develop these skills, having them first draw a picture then write a sentence such as "old salary minus 85% of old salary equals new salary of $500,000." These strategies need to be emphasized more when students first learn algebra.

Bernard Madison, Mathematics Professor at the University of Arkansas and first president of the National Numeracy Network, similarly notes that real world quantitative problems are "entangled in contexts that are often confusing, inexplicit, and incomplete. Once we untangle and clarify the quantitative content [within] these contexts, the mathematics or statistics may be elementary, but the contexts and reflection of our results back into the contexts are often sophisticated and complex."[29] To give his students practice working with quantitative analyses in authentic contexts, Madison has developed over a dozen case-like applications based on newspaper and magazine articles.[30] In my classes, too, students analyze data from various sources and claims in the media. I challenge my students to question headlines with astounding numbers. Exactly how was that value calculated? Is it reasonable? These applications of quantitative reasoning ripped from the headlines keep the students from being able to ask the dreaded question "When will I ever use this math?" Students see the relevance immediately and are actively engaged in the application of the logic, mathematics, and statistics. Presumably, such motivated students will learn the material, retain it, and be able to apply what they learned in other situations.

Summary of core QR skills needed in business

So what skills matter most in business? In terms of mathematics content areas, while calculus is undoubtedly important for high finance and some other specialty fields, the core areas of arithmetic, algebra, mathematical modeling (especially linear versus exponential growth), logic, and basic statistics are most often applied in the business world. Students need to work extensively with percents and ratios in real contexts. They need to develop a questioning mentality. They need to learn to estimate, to "guess and check" so they are not fooled by the black box of computer computations. It is practice with *applications* of the core mathematics skills that students need most. Learning to solve for x in an algebraic equation is a necessary but not sufficient condition for being able to solve a real world problem involving algebra. Students need practice with messy, loosely-defined problems in authentic contexts and need to tackle such problems from beginning to end. A complex, real-world problem requires formulating a multi-stepped plan for addressing the question, tracking down relevant information and making realistic assumptions, estimating the answer, performing required calculations (which often require the use of calculators or computers), evaluating the outcomes, and communicating the findings. Communications skills cannot be emphasized enough. Developing a language for communicating clearly about quantitative topics is essential. Skills in mathematics, logic, and statistics combined with the ability to question assumptions, plan approaches, and communicate findings are critical in the business world and in our quantitative world at large.

How can we help teachers prepare students for QR and the business world?

The lessons above provide important implications for the revitalization of teacher training and the improvement of curricula for students in K–12 schools and for undergraduate students in our nation's colleges and universities. To help students develop and retain the kinds of quantitative skills that they will apply in the real world, especially in business, we need to move away from a fragmented teaching and learning approach to a more holistic one. In particular, we need to offer more opportunities for students to make *decisions* that involve information-gathering and assessment, quantitative analyses, and communications about quantitative topics, not merely textbook *calculations* that use mathematics. Schools still need to teach English and mathematics, and separately at times, but then they also need to help students combine their research, mathematics, logic, reading and writing skills in various contexts—be it in a physics, chemistry, or biology laboratory or in a history, social studies, or economics class. In short, schools must not only teach mathematics; they must also provide opportunities to practice quantitative reasoning. The differences between the two are characterized in Bernard Madison's table below.[31]

Mathematics	**Quantitative Reasoning**
Power in abstraction	Real, authentic contexts
Power in generality	Specific, particular applications
Some context dependency	Heavy context dependency
Society independent	Society dependent
Apolitical	Political
Methods and algorithms	Ad hoc methods
Well-defined problems	Ill-defined problems
Approximation	Estimation is critical
Heavily disciplinary	Interdisciplinary
Problem solutions	Problem descriptions
Few opportunities to practice outside the classroom	Many practice opportunities outside the classroom
Predictable	Unpredictable

What needs to happen for teachers to routinely provide such QR opportunities for their students? First we need mathematics teachers to become well-versed in authentic mathematics applications from a variety of disciplines. Such applications may come from the sciences, the social sciences, and even the arts. Personal finance and business applications may be particularly useful in applied mathematics courses. Additionally, mathematics teachers need to become comfortable assigning and grading writings on quantitative topics. These assignments can start small: "Write a sentence that explains your results in context" or "Write a paragraph describing the graph you created." Mathematics teachers also need to rely less on artificial text book problems and assign more loosely-defined problems such as Fermi puzzles and case studies—not full-blown HBS cases but real world problems from newspapers, magazines, and journals. Responsibility for developing students' QR skills cannot be placed in the hands of mathematics teachers alone, however. Teachers in quantitative disciplines and in English classes need to jump on the QR bandwagon, as well. Social studies and science teachers, for example, might be challenged to assign more papers requiring students to describe supporting tables and graphs. Writing teachers might move toward more assignments requiring the presentation of quantitative evidence. And teachers in quantitative disciplines need to be patient enough to remind students of the mathematics, logic, and statistics needed to be combined in new applications in their subject areas.

To help teachers stretch in these ways, teacher education programs and in-service training programs need to provide more interdisciplinary opportunities. While training at the elementary school level tends to do this, secondary school training becomes much more discipline specific. The only way to get students to combine their information literacy, mathematics, and communications skills within various contexts is to train teachers to do the same. Teachers of mathematics and a variety of quantitative disciplines might benefit from courses in the case study method or project-based learning. These methods naturally require one to work in teams, enhancing problem-solving and communication skills. Workshops specifically designed to offer teachers examples of good interdisciplinary QR projects might also be offered to teachers. I taught such a week-long summer workshop last year to secondary school mathematics teachers in Virginia. Those workshop attendees expressed a strong desire for more curricular materials that they could easily use in their classrooms.

K–12 teachers have so many demands on their time that they do not always have the time to create interesting QR exercises from articles in last Sunday's *New York Times*. If states become more explicit about student expectations in quantitative reasoning rather than in mathematics *per se* (on their standards of learning and standardized assessments, for example) then perhaps publishers will recognize the demand for more authentic QR exercises and will provide such resources for teachers. Such resources already exist at the elementary school level. For example, TERC, a non-profit education research and development organization dedicated to improving teaching and learning in math, science, and technology, offers the *Investigations in Number, Data, and Space* curricular materials. These "activity-based investigations encourage students to think creatively, develop their own problem-solving strategies, and work cooperatively. Students write, draw, and talk about math, as well as use manipulatives, calculators, and computers."[32] Similar multidisciplinary, activity-based materials need to be offered for secondary schools as well, where, as mentioned earlier, the tendency, unfortunately, is for schools to fragment the learning into distinct disciplines.

In colleges, as well, collaborative efforts to develop students' QR skills need to be encouraged. Team-teaching seminars or courses on quantitative, interdisciplinary topics might be helpful. I recently had the pleasure of team-teaching a new course in statistics in the biological sciences. I have not had biology since 9th grade but I know a good deal about teaching statistics and my co-teacher had never before taught statistics but is an expert in ecology and has done many statistical analyses in his biology research. Developing and teaching this course was an excellent opportunity for each of us to expand our own QR skills in new directions and our enthusiasm apparently carried over to our students, who reported gaining a great deal from this class. I can envision many other collaborative efforts that would allow students additional opportunities to develop QR skills that will help them throughout life. To succeed in business, students need to develop those “habits of mind” of questioning quantitative evidence, analyzing problems, and communicating about quantitative topics. The applications need not come directly from the world of business; they can be from a biology or history course or the front page of the newspaper.

Conclusion

To best prepare students for the highly quantitative real world of business, teachers need help in creating authentic, complex problems that integrate math, research, technology, and communication skills. Students need interesting and practical examples to make it abundantly clear that mathematics skills are applicable in the real world. Students need to be able to find information or make assumptions for “messy problems,” plan a reasonable approach to a problem, apply mathematical techniques, check for the reasonableness of the answer, and communicate the findings including decisions. Students need to develop a questioning mentality.

Back to the *Telebomb* example, we would like to ensure that upon hearing of the “half trillion dollar aggregate cost” of the telecommunications bust that people would immediately question where that figure came from. Over how many years was that cost accrued? Over what geographical space? Just the US or the world? Exactly what costs were included and why? This number sure sounds big—is it really? Relative to what? When our nation’s schools and colleges produce citizens who routinely question such headlines and ask those types of quantitative questions then we will have a population that is not only prepared for the business world but is prepared for the myriad quantitative issues of everyday life.

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TERC. (n.d.). Investigations in number, data, and space. Retrieved May 2, 2007, from www.terc.edu/work/440.html. TERC began in 1965 as the Technical Education Research Centers.

Endnotes

[1] For an excellent discussion of the difference between what Alan H. Schoenfeld describes as "school mathematics" and what is known as "quantitative literacy" or "quantitative reasoning" see *Mathematics and Democracy: The Case for Quantitative Literacy* prepared by the National Council on Education and the Disciplines, especially the case (the first chapter) by Lynn Steen and the Design Team and Schoenfeld's essay "Reflections on an Impoverished Education."

[2] Handley, p. 64.

[3] *Ibid.*

[4] See pp. 9–15 of the first chapter of Mathematics and Democracy for examples of the many ways that QR skills are needed in citizenship, medical decision making, and personal finance.

[5] This figure is from the Graduate Management Admission Council, the organization that provides the GMAT. For more about this organization, see www.gmac.com/gmac/aboutus/.

[6] For more details on each section of the GMAT, see www.mba.com/mba/TaketheGMAT/TheEssentials/WhatIstheGMAT/GMATOverviewNEW.htm.

[7] For more details on these two kinds of quantitative problems, see www.mba.com/mba/TaketheGMAT/TheEssentials/WhatIstheGMAT/QuantitativeSectionNEW.htm.

[8] Now that the GMAT, like many other standardized tests, is administered on line, it will be interesting to see whether future versions of the test move away from "multiple-guess" problems toward open ended questions. The relatively new Collegiate Learning Assessment, with its open-ended performance tasks, is discussed later in this paper.

[9] Personal communication with Richard Cleary, April 21, 2007. Bentley College in Waltham, MA offers both undergraduate and graduate business programs.

[10] See the "elements" of quantitative literacy, pp. 7–9 in "The Case for Quantitative Literacy," the first chapter of *Mathematics and Democracy*.

[11] Personal communication with Richard Cleary, April 21, 2007.

[12] *Ibid*.

[13] The case method was pioneered at Harvard Business School (HBS) in the 1920s and today more than 80% of HBS classes are built on this method, according to the school's Web site. www.hbs.edu/case. Other highly ranked business programs, such as Stanford's Graduate School of Business, also use case studies to a high degree, but more often employ other teaching methods including simulations, discussions, problem-solving sessions, role-plays, etc. www.gsb.stanford.edu/mba/academics/learning_methods.html.

[14] From www.hbs.edu/case/hbs-case.html.

[15] *Ibid*.

[16] The six categories of questions listed are commonly known as Bloom's Taxonomy, from Bloom *et al*., 1956.

[17] This section is taken from the homepage of the Collegiate Learning Assessment (CLA) Project, at www.cae.org/content/pro_collegiate.htm.

[18] Personal communication with Beth Reiland, March 27, 2007. The Exeter Group is a technology consulting firm in Cambridge, MA.

[19] Personal communication with Beth Reiland, March 27, 2007.

[20] Page 7, *How Would You Move Mount Fuji?*

[21] Pages 81–82. These are just three of about 40 questions presented along with reasonable approaches to answering the questions in Poundstone's book.

[22] Poundstone offers more detailed tips on how to approach these kinds of interview problems in chapter 8.

[23] Much more detail about McKinsey's interviews can be found at www.mckinsey.com/aboutus/careers/applyingtomckinsey/interviewing/index.asp.

[24] Calculation based on data on the employment size of firms from the Small Business Administration's Office of Advocacy, www.sba.gov/advo/research/us_04ss.pdf.

[25] See the "Small Business Planner" at www.sba.gov/smallbusinessplanner/index.html.

[26] *Ibid*.

[27] Personal communication with Robert Berney, formerly of the SBA, March 20, 2007.

[28] William Briggs's presentation at the Northeast Consortium on Quantitative Literacy's annual meeting, Vassar College, April 28, 2007.

[29] From "What is a course in QL," by Bernard Madison, in the National Numeracy Network's May 2005 Newsletter.

[30] E-mail communication with Bernard Madison, May 2, 2007.

[31] Bernard Madison's presentation at the Northeast Consortium on Quantitative Literacy's annual meeting, Amherst College, April 29. 2006.

[32] For more on the TERC Investigations curriculum see www.terc.edu/work/440.html. TERC began in 1965 as the Technical Education Research Centers, but is known now as TERC.