Math and Science Preparation in America

What, When, and How Much?

I. **The Critical Questions**:

A. What is the impact of the math and science knowledge and skills on the nation's economy and our global positioning? What skills are required for today's and tomorrow's jobs?

B. What statutory, regulatory, and policy practices are now in place that factor for or against increased math and science education?

C. What personal attitudes – by employers, parents, students, and school administrators – affect acquisition of math and science knowledge and skills?

D. How does our "culture" affect attitudes? Why do young people and adults from other cultures approach math and science education differently?

E. How much – and what content – of math and science do our young people need?

II. **The Facts –and How People Interpret and Use Them**

There is no national consensus regarding math and science education, nor the skills and skill levels needed for work. Even among people who agree we need "more," there is disagreement about how much more and exactly what kind of "more" we are talking about. **Math** encompasses basic arithmetic, algebra, geometry, calculus, trigonometry, metrics and measurements, statistics and probability, differential equations, fractals, and even accounting. It also includes tools of math: using excel formulas, calculators, and measuring devices. It includes the ability to make meaning out of how numbers are presented in graphs and charts. **Science** is not just biology, chemistry, physics, and earth science (the usual high school choices), but also computer science, astronomy, meteorology, and much more (but not "political science," which is an oxymoron reflecting how we abuse the concept of what science is).

What parts of this body of knowledge do people need to be successful in our economy? At what level does *everyone* need to be proficient, versus the level needed by only a few?

The Facts

Let's look at some of the data presented in the popular media and various reports.

- Percentage of undergraduate degrees in science and engineering:
    - 66% in Japan
    - 59% in China
    - 32% in the United States[1]

- Change in engineering degrees:[2]

	1985	2000	Change
China	79,556	207,459	+161%
South Korea	23,539	56,508	+140%
United Kingdom	9,630	20,280	+111%
United States	**74,425**	**59,536**	**-20%**

- More than half of all engineering doctoral degrees from U.S. Colleges go to non-U.S. citizens:[3]

Total	5,502 (2001 data)
U.S. Citizens	2,139
Non-U.S. Citizens	3,068
Citizenship Unknown	295

- 53% of American 12th graders reported they were taking a science course, while the international average was 67%. [4]

- 66% of U.S. 12th graders reported taking a math course, compared to the international average of 79%.[5]

- 4th grade students in the U.S. score above the international average in math and near first in science. By 8th grade, they score below the international average in math and only slightly above it in science. By 12th grade, U.S.

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[1] *Regaining New York's Competitive Edge: Increasing Engineering, Math, and Science Majors;* Commission on Independent Colleges and Universities; January 9, 2006
[2] "A Winning Formula?"; Joe Robertson; Kansas City Star; Sunday, April 9, 2006
[3] ibid
[4] National Center for Education Statistics, 1998
[5] ibid

students are near the bottom of a 49 country survey in both math and science, outperforming only Cyprus and South Africa.[6]

- The U.S. ranks 17th in the preparation of college-age students earning science and engineering degrees, down from third place several decades ago.[7]

- About 96% of high school seniors in 2004 were able to perform simple arithmetical operations with whole numbers, and 79% could handle simple operations with decimals, fractions, roots, and powers (which means 21% could *not* handle these simple operations). About 62% could do simple problem solving in mathematics, and just 35% demonstrated an understanding of intermediate-level mathematical concepts.[8]

- Nearly a third (32%) of high school seniors in 2004 who expected to earn a 4-year college degree had not mastered level 3 math (simple problem solving requiring the understanding of low-level mathematical concepts). A fifth (20%) of those seniors who expected to earn a professional degree could not perform simple problem solving at a mastery level.[9]

> "There are two changes to the curriculum that I would make, if I had the ability, though they might only affect higher level students. I would remove pre-calculus and calculus from the curriculum and replace them with linear algebra and discrete mathematics. Both courses require no concepts beyond basic algebra, so they would fit in perfectly. I included the linear algebra since it has such a profound effect on the way you view mathematics. Due to the emphasis that it places on modeling, I believe that it would help students to see how this material can be useful in daily life. Also, if I exclude assignments done for physics classes, then linear algebra and discrete mathematics are the only two math courses that I have ever used.
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> *Indiana University Physics Graduate Student*

Will Increasing Course Requirements Raise Achievement?

From the facts above, it is clear that U.S. teenagers are not competitive with their international peers in math and science knowledge. What is not clear is whether increasing math and science ***course*** requirements for high school students will have any impact.

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[6] *Regaining New York's Competitive Edge*
[7] ibid
[8] *A Profile of the American High School Senior in 2004: A First Look;* U.S. Department of Education, National Center for Education Statistics; October, 2005
[9] ibid

In one analysis, the Commissioner of the National Center for Education Statistics found **little relationship between scores achieved on international math tests and number of courses taken**. Swedish students scored the highest in science on the international test, yet only 43% of their students were taking 12th grade science compared to 53% in the U.S. The poor performance of the U.S. students was ascribed to the quality, not the quantity, of science course work. The number of math courses taken was similarly not found to factor into America's poorer showing on international math tests.[10] The American curriculum has been criticized for being broad and shallow, while competing nations' are narrow but deep.

Comparing 8th Grade Math Instruction in the U.S. and Japan[11]

United States	Japan
• Textbook covers **35 topics** • Less high-level mathematical reasoning • Teachers set a goal to teach students to do something • Teachers report they are familiar with recommendations for reforming math instruction, although only a few were observed to apply key recommendations for reforming math instruction.	• Textbook covers **7 topics** • More high-level mathematical reasoning • Teachers set goal to help students learn how to do something and also understand mathematical concepts so they can solve future problems. • Teachers widely practice what U.S. mathematics reforms recommend.

Between 1978 and 1996, enrollment in higher math courses increased dramatically. **Algebra 1 enrollment increased** from 76% to 91% of all 17 year olds, and **Algebra II enrollments increased** from 37% to 50%. Yet, **math scores on the National Assessment of Educational Progress rose only 2.3%**. The percentage of students who could solve multi-step problems and use beginning algebra remained **unchanged at 7%.** *More* did not equal *better*.[12]

The Principal of Bethesda-Chevy Chase High School has said her school doubled the number of students taking honor and advanced placement courses, but that there is a huge disconnect between grades and learning achievement. "Eighty percent of students enrolled in a course, such as biology, passed the course, but only 30% passed the [Montgomery County] exam."[13] Enrollment in a course, and even passing the course, does not equate to *achievement.*

[10] "Should High School Graduation Requirements be Increased?" Granger Meador; April 13, 1999
[11] ibid
[12] ibid
[13] "High Schoolers Lacking in Math, Science Courses;" George Archibald; The Washington Times; April 29, 2004

How and When Classes are Taught Impacts Future Skills

As stated above, American students' math and science learning is broad and shallow. It is also compartmentalized and taught too late. "The U.S. is unusual in that most countries do not teach science in separate courses such as Biology, Earth Science, Physics, Chemistry, and so forth. Instead, most international students study more than one science area simultaneously. Also, the science general knowledge requirement in the TIMSS [Third International Math and Science Study] was most equivalent to ninth grade work internationally, but such content does not appear in the United States until the eleventh grade… The TIMSS indicts the U.S. mathematics curriculum as overly broad and repetitive when compared to other countries. This helps explain why the math general knowledge of the TIMSS was most equivalent to seventh grade work internationally, but most equivalent to ninth grade work in the United States. Algebra and many geometry topics are introduced relatively late in the U.S."[14]

How Much Math Do We Need to Know?

Recommendations vary, depending on your profession, your goals, and your stage in life. Some pointers:

» Calculus:

This remains the gateway discipline for all of engineering and science, plus finance. B-school grads with strong calculus find far more opportunities.

Career Tip: To sidestep calculus is to slam shut doors to growing realms in the 21st-century job market, including many of the most lucrative.

» Statistics and Probability

Standard in social sciences, they will become core skills for businesspeople and consumers as we grapple with challenges involving large data sets. Winners will know how to use statistics—and how to spot when others are dissembling.

Career Tip: They'll come in handy whether you're building financial models at Goldman Sachs or marketing plans at Ford. (Parents take note: Children who really understand probability won't squander savings on state lotteries.)

» Algebra and Geometry

Key stepping stones to calculus. Mathematicians say that algebra is central to problem solving and that geometry's proofs and theorems prepare for the rigors ahead.

Career Tip: You may associate geometry with floor tiling, but it is one of the hottest fields in math today. Advanced geometry is key to designing search engines, including Google's. But the geometry used at this level comes after calculus.

» Math Tools

Though disdained by many mathematicians, Microsoft Excel is a vital tool for generalists. Those who master it and some add-ins, whether in advertising or law, can produce statistical analysis and reports that their unschooled colleagues can't touch.

Career Tip: Many workers coming out of college and grad school already master Excel. It's midcareer workers who really need the training.

Source: www.businessweek.com, January 23, 2006

Countless thousands of incoming college students must take remedial math because they did not master essential skills in their K-12 education. The problem begins in the elementary school years. Lack of mastery in elementary school leaves students poorly prepared for middle school. Slightly worse performance in middle school leaves students with a growing sense of failure and less prepared for high school. The progressive impact of poor skills is reflected in the results of international math and science tests. American fourth graders perform relatively well on such tests; eighth graders perform

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[14] Meador, 1999

significantly less well, and 12th graders' performance is embarrassing. Simply "passing" middle school math does not mean a student has developed the level of mastery to succeed in high school algebra.

A researcher at the University of Wisconsin states, "The reasons for this situation are not hard to find, and the fault does not lie with the students. Far too many of them simply do not receive a proper mathematical education in K-12, regardless of the curriculum that may have been used in their schools. If essential skills in arithmetic, algebra and geometry are not adequately developed early on, these deficiencies will build up over time, and when the student enrolls at a university, they are usually hard to remedy. A lack of mathematical background becomes increasingly difficult to overcome as courses reach higher levels. Once students have fallen behind it becomes almost impossible to catch up. As a consequence of a deficient K-12 background, these mathematically deprived students are denied the opportunity to unleash their natural talents in areas such as science, engineering and economics… Of particular concern are the often deficient math skills of prospective elementary school teachers that we see in the college classroom; this most certainly has a direct impact on the quality of their instruction, thus perpetuating the vicious circle of low performance."[15]

Another report agreed that K-12 students are often taught science and math by unqualified teachers, noting that 56 percent of high school students taking physical science were being taught by teachers who didn't major or minor in the subject in college. For math, the percentage of "out-of-field" teachers was 27%. Middle school teachers were found to be even less qualified, with 93% of science students and 70% of math students being taught by out-of-field" teachers.[16]

> "Grade school teachers are notoriously bad at science and math but then I think most people who are really good at science and math would <u>not</u> want to teach elementary classes where they are truly needed. By the time most kids get to high school they have learned that they can be more successful manipulating the system than actually learning anything."
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> *Carmel, Indiana High School Biology Teacher*
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> "My impression of elementary school level science instruction is that it's presented as fun and game-like. My impression of my own students has been that roughly ninety percent expect science to be entertaining- if they're not having fun, they think they're not learning anything, and their own pre-judgment hinders their scientific understanding."
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> *Brownsburg, Indiana High School Physics Teacher*

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15 "Keys to Success: What Students Should Learn in Mathematics;" Alejandro Ádem, University of Wisconsin-Madison; http://www.ed.gov/rschstat/research/progs/mathscience/adem.html posted 9/14/2004
16 Raptor Education Foundation, http://www.usaref.org/ELiteracy.htm posted 9/14/2004

"How can anyone expect a K-12 teacher who has no experience in the field to get a student excited about science or mathematics? It rarely happens! The **National Research Council** reports that only 30% of students who enter a science track in grade 9 are still interested in science as a major when they graduate from high school and enter college.[17]

The President's proposals to increase math and science education will require about 100,000 new math and science teachers to be found, when many school districts are struggling to fill vacancies now.[18] Where these teachers will come from is anyone's guess, but is clear that they are needed at the elementary school level, not just teaching specific math and science courses in the later grades.

> "Even raising salaries to a higher level does not make teaching an attractive alternative to industry since most math and science trained individuals want to be able to get ahead based on their merit and not their seniority. The other drawbacks are the brainless courses and bureaucracy you must put up with in the teaching world. Around Philadelphia and in New Jersey there are school districts where the average teacher makes $65-80k with a much better pension and benefit plan than is available in industry, yet the science and math majors are still not beating down the doors to become teachers. Of the engineers I know who were forced out early from AT&T, there is only one I know of who was going for a teacher certificate and as far as I know he gave it up due to the stupid courses he had to take. So I'm afraid money alone is not the answer. The systems of the [education] industry are a deterrent."
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> *Recently Retired AT&T Engineer, Bethlehem, Pennsylvania, March, 2006*

The Impact of Culture…or, Aren't All Asians Good at Math?

According to a study by the North Central Regional Education Laboratory,

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[17] ibid

[18] "SMART, Science, and the State of the Union;" Updates, Analysis, and Commentary on Today's Education Issues; www.educationsector.org, March 6, 2006

the cultures of various ethnic groups makes a difference in school performance."[19] The report explains that **parental expectations** play an important role for explaining the white-Asian achievement gap for all major Asian immigrant groups.

The culture in the United States is such that we have come to regard math as being a natural ability instead of something mastered through hard work. It is not OK to say "I'm just not good at reading." In our culture, that might imply a lack of intelligence. But it is perfectly acceptable to say "I'm just not good at math," and be greeted with smiling nods of camaraderie and no loss of esteem.

One study found that over half of the parents in Washington State seldom, if ever help their children with math homework, and the major reason given for not doing so is "the math curriculum is too complicated these days." In Massachusetts, 42% claimed it was too complicated and 25% said they were just never any good at math.[20] "Americans and American parents tend to be more likely to believe math is an innate talent, versus something that is both important and you can actually learn."[21]

American students are also more likely to ascribe their failures to an external source, like schools and teachers, instead of looking internally to their own work

March 6, 2006 e-mail to the faculty of an affluent suburban community in central Indiana. Notice any trends among the names?

The following students will be out of class tomorrow 5th and 6th Periods to take a **national math exam.** Thanks, Chair, Math Dept.

TAN	KANG
ADAM	TIDD
CHRISTO	ZHAO
DAVID	AISEN
DUKE	KIM
SACHIN	MAJUMDAR
XINGPING	YANG
PAUL	HUTCHINS
YIFAN	WANG
SHIFANG	ZHANG
JAMES	SKOOG
HAO	SHEN
KENNETH	ZOU
RUOFAN	ZHONG
ZIWEI	XIA
KEVIN	YANG
LAUREN	PENG
DANIEL	LEE
JOSHUA	STAMER
YUNGPENG	YANG
DEWEI	XIE
LUKE	CHU
CHANGYUE	SHIUE
YINGXUE	WANG
KEVIN	LI
YIFAN	LI
PETER	MENG
EVAN	TING
KEUN UK	YIN
CHENFEUI	LU
ERICA	ALLABY
MELINDA	JI
ALEXANDER	KRALL
LINXI	ZHANG
WILLIAM	BALCHAN
ROHIT	SANTHAKUMAR
HANSI	CIMINO

* Note: the first and last names have been re-arranged to protect the identity of individual students

[19] "Different Factors Affect the Academic Achievement of Asian and Latino Immigrant and Second-Generation Students;" research by Carol Schmid; North Central Regional Education Laboratory

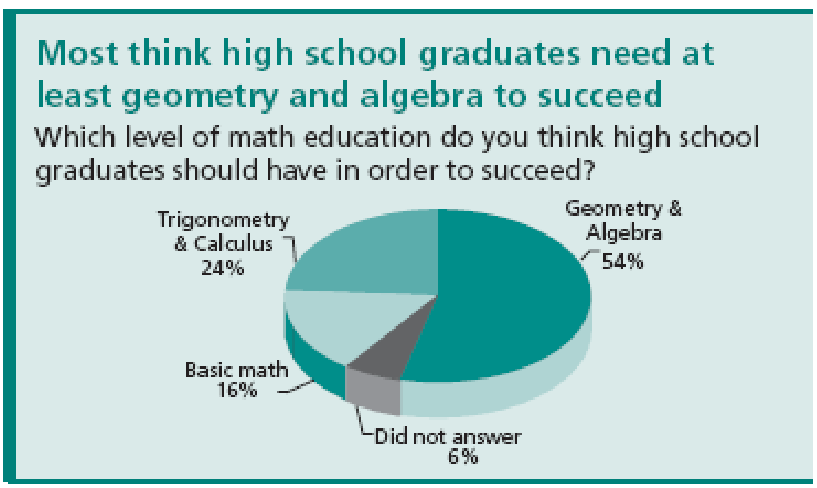
[20] "More Math, Please;" Mass Insight Education and Research Institute; 2004

[21] "Too Few Teach Math, Science;" Lori Higgins, Free Press Education; February 14, 2006

ethic. "When asked to identify the most important factors in their performance in math, the percentage of Japanese and Taiwanese students who answered 'studying hard' was twice that of American students. American students named native intelligence, and some said the home environment. But a clear majority of U.S. students put the responsibility on their teachers. A good teacher, they said, was the determining factor in how well they did in math. 'Kids have convinced the parents that it is the teacher or the system that is the problem, not their own lack of effort.'"[22]

Once U.S. students experience failure, they are reluctant to work harder and try again. They just give up. Columbus, Ohio found that more than one in four district students fail basic algebra each year and a quarter flunk biology. "Few try again; some drop out of school." [23] Indianapolis Public Schools has identified a failure rate as high as 50% for the tougher courses.

American school students reflect their parents' attitudes. A survey conducted by Public Agenda found that while most parents agree with the general goal of increasing math and science preparation, they don't think their children or their local schools have any problem.[24] In the Massachusetts/Washington study, over half of those surveyed think geometry and algebra are sufficient levels of math for students to succeed in life. Only 24% think trigonometry and calculus are needed for success.[25]



[22] "For Once, Blame the Student;" Patrick Welsh; USA Today, March 8, 2006
[23] "Some Kids Say Schools are Plenty Tough Now;" Jennifer Smith Richards; The Columbus Dispatch; February 26, 2006
[24] "SMART, Science, and the State of the Union;" Updates, Analysis, and Commentary on Today's Education Issues; www.educationsector.org, March 6, 2006
[25] "More Math, Please;" Mass Insight Education and Research Institute; 2004

School administrators echo parents' attitudes. In Idaho, hundreds of people debated their views last October on the State Board of Education's proposal to increase graduation requirements, including four years of math and science. A high school principal thought it was a good idea, but not if it meant cutting other valuable programs or having to hire an unrealistic number of math teachers.

Illinois surveyed its school superintendents in 2004 regarding their opinions on a variety of issues, including increased graduation requirements. Illinois has low expectations compared to most other states (3 years of math and 1 year of science). In response to a question about increasing the requirements, the majority felt it should be left unchanged.[26]

Response	**N**	**%**
Leave requirements unchanged	224	53.7%
Adapt a college core requirement for all students	79	18.9%
Increase the number of specific courses in math and science for graduation	55	13.2%
Increase the number of courses required but allow guidance counselors to determine the pattern of courses taken in order to meet the minimum	38	9.1%

The superintendents believed the greatest obstacle to student learning by-far is socio-economic conditions.[27]

Response (Obstacles to Student Learning)	**N**	**%**
Socio-economic conditions	197	46.6%
Rules and regulations	73	17.3%
State laws	68	16.1%
Unions	44	10.4%
Parents	30	6.9%
Boards of education	9	2.1%
Religious Groups	1	.2%
Community Members	1	.2%

Socio-economic conditions are indeed closely connected to poor school performance. The National Assessment of Education Progress analyzed student

[26] *Illinois State Superintendent's Survey 2004: Analysis and Findings*; Durflinger and Hunt; Center for the Study of Education Policy, Illinois State University;
[27] Ibid

achievement in 2000 relative to the poverty level of public schools and found that schools with high percentages of youth in poverty have lower test scores. And, students who are not personally eligible for a free or reduced school lunch, but who attend schools with high rates of poverty, were found to score lower than those schools with lower rates of poverty. [28]

Another study that found the top schools in the research area had school performance scores four or five times greater than the bottom ones. A regression analysis determined that 85% of the difference in school performance was associated with differences in the percent of students on supported lunch, and that while performance could be raised, improvement really could not reduce the impact of poverty on performance.[29]

Engineering and Scientist Shortages in a Global Economy

The primary reason for wanting to increase math and science requirements is that without large numbers of engineers and scientists, the U.S. will lose its competitive edge and fall behind in the global economy. *Regaining New York's Competitive Edge: Increasing Engineering, Math, and Science Majors*, issued by the Commission on Independent Colleges and Universities January 9, 2006 postulates that "The U.S. is a superpower largely on its leadership in science and technology, therefore, it is vital that we prepare our future generations to replace our current scientists and engineers."

Researchers at Duke University maintain that statistics showing the U.S. falling behind in engineering degrees don't take into account how differently each country categorizes a degree as "engineering." The categories of graduates counted in the engineering field are different from one country to the next. If the same definitions were applied across the board, the United States produced 137,400 engineers in 2004, compared to 351,500 in China and 112,000 in India. The researchers say that if you compare these numbers to population size, the United States produces more engineers per capita than either China or India.[30]

Other researchers acknowledge that the U.S. is slipping, but think we are taking the wrong approach to the issue. In an article titled *Collaborative Advantage* that appeared in the Winter, 2006 edition of Issues in Science and Technology, the authors warn that the days of U.S. technological domination are over. In

[28] National Center for Education Statistics, www.nces.ed.gov

[29] *Missing Piece in the Debate on School Performance*; by Walter R. Tschinkel, Professor of Biological Science, Florida State University

[30] "Talk of U.S. Crisis in Math, Science is Largely Misplaced, Skeptics Say;" Debra Viadero; *Education Week*; Vol. 25, NO. 28, March 22, 2006

contrast to the *Regaining New York's Competitive Edge* publication, the article warns:

> "It seems clear from our interviews…that efforts to solve the perceived U.S. technology problem by emphasizing policies to induce more U.S. students to major in engineering are no more likely to succeed than did similar efforts made in response to the Japanese challenge. **None of the engineering managers we interviewed mentioned a shortage of new graduates in engineering as a problem.** Indeed, some managers said **they would not recommend that their own children go into engineering,** since they did not see it as a career with a bright future. Several said they were not allowed to increase 'head count' in the United States at all; if they wanted to add engineers, they had to do it offshore. **Increasing the numbers of engineers coming into the system might do no more than raise the unemployment rates of engineers.** In fact, if increasing the short-term supply of scientists and engineers leads to increased unemployment and stagnant wages, it will further signal to students that this is not a good career choice."

The authors reached a very different conclusion than did New York because their policy recommendations were based not just on numbers of students and test scores, but on observation of how a global economy works. They recommend:

- The nation should develop strategies less focused on competitive or even comparative advantage and **more focused on collaborative advantage**.

- The U.S. should help create a world based on the free flow of science and technology (S&T) brainpower rather than "a futile attempt to monopolize the global S&T workforce."

- The nation should develop an S&T education system that teaches collaborative competencies rather than just technical knowledge and skills. "It is not the technical education but the cross-boundary skills that are most needed (working across disciplinary, organizational, cultural, and time/distance boundaries)."

Cultural and self-perception issues affect our policy decisions. The authors encourage the country to move away from dominance and toward an approach "in which leadership comes from developing and brokering mutual gains among equal partners. Such 'collaborative advantage' …comes not from self-sufficiency or maintaining a monopoly on advanced technology, but from being a valued collaborator at various levels in the international system of technology development." The American culture, however, places tremendous value on competition and dominance, for individuals as well as for the nation. Collaborative approaches to solving problems, which results in multiple winners, are neither taught nor appreciated. Winning – and being the only winner at the top – is what it's all about.

> "This nation is ruled more by social norms and politics than it is by rational thought. Scientific issues in the news are treated as debatable topics, as if passing a law could suddenly make gravity disappear or force the value of pi to be exactly three (true story- In 1897 the Indiana House of Representatives unanimously passed a measure redefining the area of a circle and the value of pi. (House Bill no. 246, introduced by Rep.Taylor I. Record. The bill died in the state Senate.) Until people understand the difference between natural law and human law, I doubt things will get any better."
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> *Brownsburg, Indiana Physics Teacher*

An article in the Los Angeles Times agrees. "More education has been the right answer to for the past few decades, but I'm not so convinced that it's the right course [for coping with the upheavals of globalization]" a recent article said, quoting Princeton University economist and former Federal Reserve Vice Chairman Alan S. Blinder.[31]

Anthony Carnevale, a scholar at the National Center on Education and the Economy notes that politicians don't consider global economic strategies, and that it is easier for them to just jump on the education band-wagon and waive the math and science flag to make America more "competitive." Blinder says "Many people blithely assume that the critical labor-market distinction is, and will remain, between highly educated (or highly skilled) people and less-educated (or less skilled) people, doctors versus call-center operators, for example…but the crucial distinction in the future may not be between the more-educated and less-educated, but between 'those types of work that are easily deliverable through a wire…and those that are not.'"

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[31] "That Good Education Might Not Be Enough;" Peter G. Gosselin, Los Angeles Times, March 6, 2006.

Do Math and Science Careers Really Pay?

- According to the LearnMore Resource Center, those who have taken the most mathematics get the best-paying jobs. About 84 percent of young workers in the 25 best-paying jobs completed Algebra II or another higher-level math course in high school, and 94 percent took geometry, according to an analysis of data from the National Education Longitudinal Survey.[32]

- Passing Algebra II and Geometry is a threshold to higher-paying careers. Algebra II is the "threshold" math course completed by students who go on to take jobs in the top half of the earnings range. Moreover, the more math beyond Algebra II, the better a person's chances of earning a salary in the top 25 percent. Geometry is the "threshold" math course for students who go on to get the highest-paying blue-collar jobs, according to research by the Educational Testing Service.[33]

> "Once I get my PhD, I will probably make as much money working in the lab as if I had just stopped with my bachelor's and gone into business. However, these business employers aren't the ones that are shouting that we need more people with a math back ground. The engineering and science firms are the ones that are claiming the shortfall, but that's mostly because they know that creating more scientists will make them cheaper to hire, not because there aren't enough to go around right now.
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> "Every time I run through the ads for physics jobs, I'll see an opening that requires a Ph.D. and five years of experience (usually in crystal physics or solid state), but only pays on the same scale as Taco Bell. While I suspect that there is still a shortage of qualified applicants for the jobs available, I also think that many jobs have remained open simply because the company has unrealistic expectations."
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> *Indiana University Physics Graduate Student*
> March, 2006

- The labor market information division of the Minnesota Department of Employment and Economic Development (DEED) examined the impact of math, critical thinking, technical design, and science skills on earnings.[34] Of the four, **critical thinking** was found to have strongest effect in discriminating between the highest and the lowest paying occupations. High critical thinking skill occupations are nine times more likely to be in the highest versus the lowest wage category.

  DEED found that high math requirements do not discriminate much between the lowest and second lowest paying occupational groups, but

[32] LearnMore Resource Center; http://www.learnmoreindiana.org
[33] Ibid
[34] http://www.deed.state.mn.us/lmi/publications/mms/page05.htm

> occupations that require high levels of math skill are nearly nine times more likely to be in the highest versus the lowest wage group.
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> Science skill was determined to be a marketable skill, but its effects on wages are somewhat less dramatic than the other three skills. **Math**, **engineering technology**, and **physics**, reports DEED, are the knowledge requirements that are most strongly associated with high wages. Physics knowledge requirements have the strongest impact on wages. Occupations which require high levels of physics knowledge are over 17 times more likely to be in the highest paying versus the lowest paying wage group. **This result is interesting, given that the vast majority of occupations require little or no knowledge of physics**; however, the occupations that do require high levels of physics knowledge are very likely to be high paying.

The last statement may be key: that the vast majority of occupations do not require the high levels of math and science skills that make America competitive. While we may need more math and science majors who subsequently turn those skill sets into marketable work and wages, it is more important for all citizens to have **mastery** of the skills they *will* use in their work lives than it is for all citizens to have a smattering of math skills that quickly fade because they are not used.

The Michigan state school superintendent said (as quoted by Upjohn Institute researchers in their testimony to the Michigan Senate Education Committee[35]), "More than 60 percent of employers report that recent graduates have poor math skills and nearly 75% report deficiencies in grammar and writing skills." However, Upjohn researchers contend that it isn't college-prep skills that graduates are lacking, but **basic math and literacy**. "If employers are reporting that the high school graduates they hire cannot read graphs, the proper response is to make sure they learn to read graphs, not to pass them on to a watered-down Algebra II course."

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[35] "Graduation Requirements, Skills, Postsecondary Education, and the Michigan Economy;" Testimony presented to the Michigan Senate Education Committee by Dr. Timothy Bartik and Dr. Kevin Hollenbeck; February 20, 2006

What Does Work Require?

When confronted with a proposal to increase high school math requirements, a 14-year old Columbus, Ohio student claims, "you only need up to seventh-grade math for most jobs" and a 15-year old said, "I'm not going to use it in life. I play tennis."[36] Are they right?

Indiana recently designed a work readiness certification system that offers Blue and Gold certificates. A Gold level certificate indicates essential skills **at a level required by 90 percent of all jobs profiled nationally** through the WorkKeys® system. The holder of this certificate demonstrates mastery of the "Level 5" applied math skills. Level 5 problems require several steps of logic and calculation. ACT's Work Keys data base contains job profiles for 4,136 jobs, and assessment results for 379,546 individuals as of August, 2005.

According to their findings, 24% of all people assessed can perform level 5 math, yet only 6% of all jobs profiled require such a level. 75% of all jobs profiled require *less* than level 5. (ACT cautions that because data is based on Work Keys users, they may not be nationally representative and should be interpreted cautiously.)

Sample Work Keys Level 5 Test Item:

Quik Call charges 18¢ per minute for long-distance calls. Econo Phone totals your phone usage each month and rounds the number of minutes up to the nearest 15 minutes. It then charges $7.90 per hour of phone usage, dividing this charge into 15-minute segments if you used less than a full hour. If your office makes 5 hours 3 minutes worth of calls this month using the company with the lower price, how much will these calls cost?

A. $39.50

B. $41.48

C. $41.87

D. $54.00

E. $54.54

As researchers from the Upjohn Institute point out, "it is simply not the case that all or even most high-wage jobs require the use of Algebra II. … We assume that most

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[36] "Some Kids Say Schools are Plenty Tough Now;" Jennifer Smith Richards; The Columbus Dispatch; February 26, 2006

of you [Michigan State Board of Education] are in relatively high-wage jobs and are doing your jobs well. Unless the majority of the state Board can pass an Algebra II test tomorrow, we don't see how you decide to deny a high school diploma to students who do not pass such as test, on the grounds that such skills are supposedly required for all high-wage jobs."[37]

Keeping in mind the example of a Work Keys Level 5 applied math test question shown in the text box, review the table below that lists the median applied math level identified for various occupations in ACT's Work Keys database of profiled jobs.[38]

Occupation	**Median Profile Work Keys Job Profiling Score (rounded to nearest integer)**
Industrial Engineers	5
Mechanical Engineers	4
Network Systems Data Communications Analyst	6
Pharmacists	6
Radiological Technologists	4
Registered Nurses	5
Respiratory Therapists	5
Tool and Die Makers	5
Industrial Machinery Mechanics	4
Solderers	5
Biological Technicians	3
Chemical Technicians	4
Computer Systems Analyst	4
Database Administrators	5
Education Administrators, Elementary and Secondary	5
Education Administrators, Postsecondary	4
Electrical Engineers	5
Electrical Engineering Technicians	6
Electricians	5
Financial Managers, Branch or Dept.	5

The important message for many high school students, their parents and counselors may not be that electrical engineers don't require as a high a level as one might assume, but that tool and die makers require the same level! Those who hoped to avoid mastering math by going in to the trades will be sorely disappointed.

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[37] Letter to Michael P. Flanagan, Superintendent of Public Instruction at the Michigan Department of Education from Timothy Bartik and Kevin Hollenbeck, Senior Economists at the W.E. Upjohn Institute for Employment Research, November 22, 2005

[38] http://www.act.org/workkeys/profiles/occuprof/index.html

Robert Lerman of the Urban Institute says "Although math skills beyond Algebra I are useful and intellectually rewarding, there are large shares of workers who will never use such skills in their jobs. The same is no doubt true of advanced classes in other subjects as well. It is true that upper level science, math, and social studies are often required by universities; it is far less obvious that such courses are vital to success in the work place. Moreover, it is not clear that the high school academic courses actually offered are the most appropriate for success in the workplace or in other aspects of life."[39]

Lerman touches on an important issue. Our concern about math and science appears more related to success at the postsecondary level than success at work. Universities are not necessarily connected to the requirements of the world of work.

"Less than a handful of studies…examine the causal link between high school course taking and productivity payoffs in the workplace….Much of the effect stems from the amount and type of postsecondary education that follows high school…The impact of Algebra II and higher-level courses disappears when an instrumental variables technique is used for estimation and when ability is controlled."[40]

Anthony Carnevale, (National Center on Education and the Economy) points out that what students take in school and what they ultimately use in the workplace have little connection. "It is true that if you're going to get a good job in America, you've got to take Algebra 2…On the other hand, when you look at college majors, and even more so when you look at occupations, the content in Algebra 2 has very little to do with either. That is, you never use that content again, …but it predicts your success in college and in the labor force. **So it is effectively a screen**."[41]

III. <u>What Questions Should We Be Asking?</u>

A. Think about whether you should be supporting increased *course* requirements, or focusing the discussion on mastery of essential *skills*.

B. Understand the opinions of all stakeholders in your region: K-12 teachers, K-12 school administrators, postsecondary instructors and administrators, young

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[39] "Career Focused Education and Training for Youth;" Robert Lerman; The Urban Institute; 2005
[40] "Graduation Requirements, Skills, Postsecondary Education, and the Michigan Economy;" Testimony presented to the Michigan Senate Education Committee by Dr. Timothy Bartik and Dr. Kevin Hollenbeck; February 20, 2006
[41] "Economic Trends Fuel Push to Retool Schooling;" Lynn Olson; *Education Week*; vol. 25. No. 28; March 22, 2006

people, parents, employers, chambers of commerce, labor unions, elected officials. How do they feel about the issue? Where are they getting their information to make decisions? What kind of a campaign would be needed to change the opinions of any of the stakeholders?

C. Learn more about the labor market in your area. What are the math and science skills and knowledge required for what jobs, and for what percentage of jobs? (Note: this is not researching course names like "algebra," but understanding specifically what kinds of functions are required and how they are applied).

D. What do careers that require high levels of math and science pay in your region? What other kinds of occupations are competing at that pay range for young peoples' attention? What are cogent reasons you could give a young person to pursue math and science careers?

E. What are the projections for increased numbers of jobs requiring certain levels of math and science skills, and numbers of replacement workers needed (i.e. the demand projections)? How many young people are in the pipeline to meet the projections (i.e., the supply)? How are employers addressing that gap (e.g., do they have a policy that no new engineering jobs can be created in the U.S.)? What is the gap you may need to fill locally?

F. What initiatives are currently underway in your schools and workplaces that can be used be used as leverage to increase math and science knowledge and skill attainment?

IV. Recommendations

- It is important that all youth attain solid mastery of 9th-grade level math and science – even if it takes them four years of high school to do it. Beginning in the first grade, no child should be passed on to the next grade or level of math or science until he/she has attained solid mastery of the level before. Mastery of a lower level of math or science is more important than poor comprehension of upper level courses.
- Elementary school math and science should be taught by math and science specialists, not general education elementary teachers.
- Children do not learn alike. Some will do best with conceptual learning, and others will learn best in an applied setting. Learning style is not an indicator of intelligence, just of style, and all styles need to be equally accommodated in schools.
- U.S. school curriculum needs to emulate that of successful foreign nations in terms of being narrow and deep rather than broad and shallow. Curricula should be integrated rather than compartmentalized.

- When an industry sector is unable to attract the best and brightest, the practices of the industry itself are examined to see what can be changed so they can attract the right talent. If K-12 education is not attracting and retaining the best and brightest, its practices need to be re-examined and new approaches used. And it isn't just about money.
- The message needs to be clearly communicated to parents and backed up by school administrators and the courts: you are responsible for your child's behavior and learning. The school is a facilitator of the learning process, but ultimately, you are accountable. Schools do not exist to "fix" your child or your lack of parenting skills.