The Science & Engineering Pipeline

Fueling the Pipeline: Attracting and Educating Math and Science Students

CONFERENCE REPORT

EMC² where information lives

Engineering in Mass Collaborative

Massachusetts High Technology Council

BRT The Business Roundtable

Northeastern University

Mass Insight Education

UMASS

Massachusetts Software & Internet Council www.msicouncil.org

The New England Council

Massachusetts Business Roundtable MBR

AIM Associated Industries of Massachusetts

AICUM

MassINC The Massachusetts Institute for a New Commonwealth

Massachusetts Technology Collaborative

EMC²
where information lives

Dear Friend:

As the lead sponsor of the conference held in conjunction with the release of this report on May 27, 2003, EMC Corporation is proud to join you in this important discussion about ways to engage more young people in math and science careers and expand the engineering pipeline. We are eager to solicit your ideas and support for ongoing programs and policies to address this timely issue effectively.

Our collective challenge reaches well beyond assuring a reliable stream of properly skilled workers. The broader reality is that all young people, whether they pursue technology careers or not, must be technically literate if they are to succeed fully in tomorrow's economy. The new federal law that requires states and schools to set and meet educational performance standards is aptly titled No Child Left Behind.

In and around our surrounding communities, EMC Corporation supports a series of K–12 educational programs that engage young people, especially girls and minorities, in math and science. We are proud of these programs and encouraged by what other corporations in the Commonwealth are doing. A primary goal of this effort is to encourage more businesses to become engaged in developing their own initiatives and solutions.

This report provides a roadmap of possibilities. Drawing on research by The Business Roundtable, it offers an overview of the technology pipeline issue. A study from Northeastern University analyzes scores of college-bound seniors from the class of 2000 on the math SAT-I test, revealing some important findings about various populations. A story about the hands-on experiences of Massachusetts teachers, students, and others involved in a range of math-, science-, and technology-related educational activities gives a look inside Massachusetts schools. Finally, MassInsight Education provides concrete steps to help pull the state out of its pipeline predicament.

We believe that business leaders must take a lead in promoting sound educational policies and in engaging in best practices with teachers and students that support the engineering and science pipeline. We hope that this effort will motivate more businesses to join with us in an expanded campaign to improve student performance and to increase interest in math and science education.

We pledge to work with all of you toward this common goal.

Sincerely,

Michael C. Ruettgers
Executive Chairman

Joseph M. Tucci
President & Chief Executive Officer

C O N F E R E N C E   R E P O R T

The Science & Engineering Pipeline

Fueling the Pipeline: Attracting and Educating Math and Science Students

Contents





Executive Summary

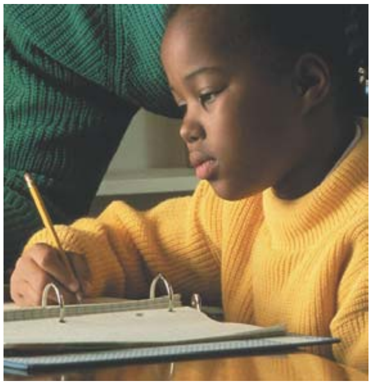
The various components that make up this report have a simple yet challenging goal: to provide information about an issue of growing importance to our economy and our society in a way that encourages corporate and other leaders toward a meaningful and lasting response.

We have a technology pipeline problem: Not nearly enough of this country's students, especially young women and minorities, are pursuing studies and careers in math, science, and engineering.

Of the students across the state who choose undergraduate science and engineering programs, a significant percentage drop out because they lack the necessary math skills to succeed. We must do more to prioritize and emphasize math and quantitative skills for K–12 students.

Many students who score well in math are not entering technical fields. The immediate result is a shortage of properly skilled employees, a shortfall that will be magnified when the economy recovers. Demographic data make it clear that the pipeline will flow only with a dramatic increase in the number of female and minority workers.

The greater, if less obvious, impact of the pipeline problem extends beyond the immediate technology sector: American society at large will suffer unless all of its citizens—regardless of background or career track—are properly schooled for life in this twenty-first century.



Though enhancing math and science education requires specific actions, such as those described in this report, it also demands what the Committee for Economic Development calls a fundamental "culture change" in the way math and science are taught.

In addition to discussing the pipeline problem, which has been well documented by a series of national reports and commissions, this report offers solutions. They are as simple and accessible as a technology company working with the local grade school to make math and science classes come alive, and as complex and daunting as challenging the very way by which we recruit and pay public school teachers.

Getting the pipeline to flow freely will not be easy, but good analyses of the issues involved enable us to make an effective start. Some best practices already on the ground provide a clear roadmap.

This report, with a mix of analysis and solutions, consists of these components:

- **A National Overview by The Business Roundtable**. Prepared by The Business Roundtable in Washington, D.C., this report summarizes recent efforts to analyze and respond to the challenge of ensuring that all students are able to master the mathematical and scientific concepts needed for careers and active citizenship in the twenty-first century. The report looks at a range of programs and policies at the national level. Some, it finds, are paying off; others need refinement and more analysis. Its overview concludes with a list of 10 major findings and recommendations that are common to various national initiatives and reports, such as:

  The importance of better teacher training, retaining good math and science teachers, a more rigorous math and science curriculum, and the alignment of standards, assessments, and curricula to build a depth of understanding.

- **The Math Proficiencies of College-Bound High School Seniors: Selected Findings from an Analysis of Math SAT-I Data for the New England States.** Authored by Northeastern University Professors Paul E. Harrington and W. Neal Fogg, this study is based on math SAT-I scores from the class of 2000. It reveals that:

  While a large number of college-bound seniors do have strong math skills, these students are not choosing to go into scientific, engineering, and information technology (SEIT) fields.

  "The educational pipeline has been unable to feed the manpower requirements of employers thirsty to expand output and employment," the paper finds.

  The paper reveals a deep gap in enrollment in SEIT-related studies based on race and gender. For example, while 25 percent of all male test-takers earned a score of 620 or higher, only 15 percent of females did as well. Math-proficient males were 3.5 times more likely than math-proficient females to say they intended to major in engineering. Harrington and Fogg also found: "The gap between the math reasoning skill levels thought needed to succeed in SEIT-related fields of study and the actual skill levels of Black and Hispanic students in New England is enormous."

- **Report from the Front Lines: A primer for business about a teacher-centered math, science, and technology strategy**. Researched and written by Phil Primack, this paper focuses on the firsthand views of teachers, students, and others in Massachusetts working on the K–12 math, science, and technology studies' front lines. It discusses the best practices of the Engineering in Mass Collaborative and uses interviews with a range of people to identify policies and programs that have successfully addressed the pipeline issue. It focuses on four key issues:

  1. The need for greater math and science efforts at the elementary school level.

  2. The importance of professional development programs for current teachers, especially those with little formal background in math, science, and technology (MST) subject matter and teaching techniques;

  3. The need for more innovative reward systems to attract and retain MST teachers;

  4. The role of the private sector in supporting pipeline efforts.

- **Policy Brief: K-12 Mathematics Achievement.** This executive summary presents a handful of ways to address the chronic shortage of qualified math teachers.

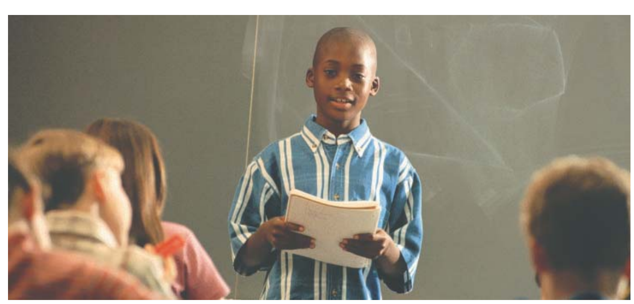
Action Items

The importance of the pipeline issue is clear. We have collected information and interviewed frontline experts, and we have seen best practices that prove the promise of public- and private-sector collaboration. Now it is time for technology and other business interests to apply what we have learned.

To measure progress, the Engineering in Mass Collaborative—a partnership of universities, industry and K-12 educators focused on the science and engineering pipeline—will prepare a report within the year, considering performance of benchmarks such as those listed here. This list is by no means complete; individual companies can best determine their own priorities.

But no company, and no sector of this technology economy, can afford *not* to get more involved in efforts to enhance math, science, and technology education.

Engineering in Mass Collaborative



At the corporate level…

By supporting and working with the Engineering in Mass Collaborative, individual businesses can initiate or expand their own efforts to improve K–12 education and, through that, their own labor supply outlook. These efforts, based on best practices by EiMC, need to be scaled up and focused more specifically on enhancing math achievement. Among other things, businesses can support:

Cooperation with local school districts as well as public and private institutions of higher education:
Technology firms can work with teachers on their curriculum, arrange field trips to company labs, and provide engineers and other professionals to speak to students about real-world experience. Companies should organize and underwrite rigorous math and science content institutes in their local school districts, building on the statewide Math Achievement Partnership.

A focus on underrepresented communities:
Building on the EiMC model, companies should form strategic partnerships with organizations working to elevate the academic achievement of students in minority communities. This includes recognizing the importance of culturally appropriate math and science teaching methods and curricula, as well as efforts to make sure that schools serving these populations have full access to technology-based classroom methods.

Teacher externships:
Companies should offer paid summer employment to local MST teachers. This benefits the teachers, who gain added income and practical experience, and the companies, who gain from the skills and perspective of the teachers.

K–12 programs:
Companies can encourage students to expand their interest in MST studies and careers in a number of ways, including scholarships to attend design camps, career fairs, and plant tours.

Recognition of local teachers:
Companies can host annual events that honor exceptional MST teachers as well as schools that do an exemplary job with MST education.

Participation in retired engineer efforts:
Current and former engineers and other technical employees should be made aware of Project RE-SEED and other programs that link their expertise to school districts seeking firsthand experience.

Release time for female and minority employees:
Professionals can provide outreach to young women and minorities, serving as positive role models in schools and with target demographic audiences.

Ongoing initiatives:
Massachusetts businesses should actively back efforts aimed at enhancing science, math, and technology education and awareness, such as MassInsight Education's K–12 Math Achievement Initiative.

EiMC Performance Measures:

Has there been a significant increase in corporate partnerships with local K–12 schools to enhance interest in math and science studies, especially in underrepresented communities?

Are companies actively pursuing curriculum and other improvements at college-level education departments in their regions to make sure that teachers are properly trained in math and science content and pedagogy?

Have companies acted to make their engineers and other technical workers—active and retired—available for direct classroom assistance?

At the state level…

Massachusetts has made great strides in improving its overall quality of K–12 education, but the state is still falling short when it comes to math achievement. The business community, which has such a direct stake in the outcome, should support:

Math Achievement Initiative:
The state should fund MassInsight Education's Math Achievement Partnership (MAP), to provide in-service teachers with intensive math content institutes and classroom coaching; place pre-service teachers in rigorous undergraduate math courses; increase math requirements for certification; attract and retain highly skilled math teachers with market-driven pay; and mobilize broad public support around the principle that *math matters* (see page 33).

Sharing Best Practices:
The state, through its Mass.gov Web site and other means, should offer links by which local school districts and others can access best practices by industry, the state, and individual districts. Among other things, such a clearinghouse role could identify best practices to solve the particular problem of keeping K–12 students who *do* have strong math skills interested in further education and eventual careers in MST fields. Retired engineers and others could also use this state clearinghouse to get involved in K–12 MST efforts.

Recruiting high-performing teachers:
The state should support the use of pay differentials and more flexible certification requirements to draw more and better-trained math, science, and technology teachers as part of a broader effort to recruit and train potential teachers from the ranks of engineers and others seeking new career opportunities. Programs that quickly but effectively train math and science Ph.D.s and other professionals to work in K–12 classrooms should be developed to tap into this rich pool of potential teachers. The working environment for all teachers must be improved to make the profession more attractive.

Better preparation of new teachers:
The state should work with graduate schools of education, the education departments of undergraduate colleges and universities, and math, science, and engineering departments to assure that entry-level teachers have been properly trained in both science and math content and pedagogy. The private sector should help develop improved curriculum for future teachers.

Expanded professional development:
Incumbent teachers should be given more opportunities for and incentives to pursue intensive, content-based professional development, including stipends and tuition for graduate credit. They should also be able to draw upon a broader range of professional development courses offered by industry and others.

A link between the pipeline issue and overall economic development:
As part of its economic development strategy, the Commonwealth should assign priority to the long-term health of its technology talent pipeline and evaluate any initiative in terms of how it would help strengthen this pipeline.

EiMC Performance Measures:

How many math and science teachers have entered the classroom via alternative certification?

Has the Board of Higher Education implemented changes in how the education departments of public colleges and universities work together with math, science, and engineering departments to train future teachers in math and science content and teaching skills?

Has there been a significant increase in the number of K–12 students—especially females and minorities—choosing math and science majors?

Working with public and private campuses, has the state developed effective ways to keep math-skilled students interested in future math and science studies and careers?

Has the Math Achievement Partnership been funded?

At the federal level…

While education is primarily a state and local issue, the federal government plays a critical leadership role by focusing the country on specific national priorities for education reform. Through its "bully pulpit" role, federal leaders should encourage all high school students to take four years of math and science. Federal funding, paired with requirements such as those set by the No Child Left Behind Act of 2001, provide leverage for improving schools. If states are to meet such goals, they must have support from Washington, both financially and through the development of national models, guidelines, educational templates, and research on math and science learning for state use. Business should support federal efforts toward:

Adequate funding:
The federal No Child Left Behind Act sets important standards. We must stay the course on standards and accountability by implementing the act and through federal support for state-led education reforms. Congress should fund the U.S. Department of Education's Math and Science Partnership program at the $450 million level authorized by the act by the time states are required to implement science assessments in 2007. This state-based program, now funded at $100 million, provides resources for states to focus on teacher training, curriculum development and other local needs to improve math and science education. Federal support should also continue for the National Science Foundation's complementary Math and Science Partnership program, which funds competitive grants for model programs.

Curriculum reform:
Tougher standards, such as MCAS in Massachusetts and accountability for student learning, have already forced states to review and update their curriculum frameworks. While it does not develop curricula for states and localities, the federal government could support consortia of states that want to work together to develop common specifications for rigorous math and science curricula, for example, encouraged the introduction of algebraic concepts into elementary school curricula to better prepare students for middle and high school math.

Better textbooks and other teaching materials:
States select their own textbooks, but the National Science Foundation and other Washington players should support efforts to develop math and science textbooks and curriculum materials that are not only rigorous and focused, but which stress the direct connection between math and science and other parts of students' lives and education.

Greater access to and use of technology:
Technology is already transforming traditional classroom methods and curricula. But more can be done to harness the tool of technology to achieve higher levels of student learning. Federal agencies, for example, could provide locals schools with regular online updates on important math, science, and technology applications. Interactive content can greatly enrich standard "chalk and talk" teaching.

EiMC Performance Measures:

Has Washington moved toward full funding of the Math and Science Partnership program?

Is No Child Left Behind being fully implemented, and is it on schedule?

Has the U.S. Department of Education been able to raise awareness of the importance of math and science education as they have successfully done with reading?

Recent National Efforts to Improve Math and Science Education

by LINDA P. ROSEN *for* THE BUSINESS ROUNDTABLE

Historically, a few of the "best and brightest" have driven the American economy through scientific innovation, while the vast majority of young people have had little interest in math and science and achieve at only mediocre levels. However, recent efforts to improve math and science education suggest having teachers with strong content knowledge and solid, systemwide support.

It is imperative that we address our education imbalance. Economic growth and civic responsibility depend on a torrent of science-based information, which in turn depends on a broad base of knowl-edgeable and skilled individuals. Unfortunately, there has never been a "golden age" of math and science achievement to serve as an example. Instead, there is knowledge and experience gained from many efforts to improve achievement in math and science that must be expanded, refined, and scaled up.

In the past two decades alone, we have seen (a) creation of national and state standards in math and in science, (b) development of curriculum materials aligned to the standards, (c) higher expectations for all students, especially those living in poverty, (d) the need for systemwide change in support of math and science, and (e) recognition of the key role of teachers in raising student achievement.

Over that same period, the scores of a representative sample of 17-year-old American students on the National Assessment of Education Progress (NAEP)—known as the "Nation's Report Card"—are discouraging. The average science score is lower today than it was thirty years ago; the average math score, though higher over the 30-year span, was stagnant in the 1990s. These national averages mask the promising gains in student achievement made by some states and school districts over the same time period.

What do we know from previous efforts?

Rigorous math and science courses show real results.

Among the array of new programs and policies, we see some that are yielding positive outcomes. For example, the concerted effort to increase the number of students—especially females—taking rigorous math and science courses in high school is paying off. The average math SAT score of the 1.3 million students headed to college in the fall of 2002 was 516, the highest level in 32 years. Female test-takers averaged a 35-year-high score of 500.

Though they still lag behind their male peers (average score 534), the gender gap has been closing. The SAT and NAEP results are not necessarily contradictory; instead, they may suggest that all students, not just those who are college bound, will benefit from sustained high expectations.

There also is evidence that states with strong systems of standards, assessments, and accountability in place are seeing achievement gains on their own state assessments and on NAEP. Massachusetts, North Carolina, and Texas have been steadfast in maintaining standards-based reform, despite challenges and setbacks. The results speak for themselves: a narrowing of the achievement gap between White and Black students, and higher passing rates on their own state tests, while showing improvement on the national barometer of NAEP.

Raising standards may yield longer-term improvement.

The linchpin of current education reform is the alignment of standards, curriculum, assessment, and staff development. The first step, of course, is the development of standards.

In 1989, the National Council of Teachers of Mathematics released Curriculum and Evaluation Standards for School Mathematics. In 1993, the American Association for the Advancement of Science released Benchmarks for Science Literacy, and in 1995, the National Academy of Sciences released the National Science Education Standards. By the spring of 2002, 49 states had completed their own math standards, and 46 states had completed their own science standards.

Yet, despite over a decade of work on standards at the national and state levels, student performance in science on main NAEP in 2000 yielded 70 percent of 4th graders, 67 percent of 8th graders, and 82 percent of 12th graders scoring only "basic" or "below basic." In the same year, math results yielded 74 percent of 4th graders, 73 percent of 8th graders, and 84 percent of 12th graders scoring at "basic" or "below basic." The news worldwide is no better; on international comparisons, American 8th graders score significantly lower in science and math than their peers from nearly all industrialized nations participating in the study.

Teachers with strong content knowledge, who know how to engage students in learning, can make a critical difference in whether or not students succeed. But excellent teaching, without systemwide support, is not enough.

Though disappointing, these results are not surprising. Most educators recognize that widespread knowledge of the standards-based movement has not yet translated into widespread change on the classroom level.

The National Science Foundation tackled another important aspect of reform: institutionalizing change in the ways math and science are taught within the larger education system. Millions of dollars were invested in systemwide math and science education in the 1990s, with state, urban, and local programs securing funds. Though there are mixed reviews of their ultimate success, there is little question about the value or difficulty of systemwide change or the need to pursue such a goal.

Better teachers give us better students.

Many programs point to the role of a highly qualified teacher as a necessary, although not sufficient, element in school success.

Research shows that teachers with strong content knowledge who know how to engage students in learning can make a critical difference in whether or not students succeed. But excellent teaching, without systemwide support, is not enough. Major investments in teacher knowledge, through summer workshops, release time for staff development, and ready access to math specialists, were linked to new curriculum materials and assessments. The student achievement results have been promising, especially in those classes where teachers' knowledge and skills increased as well.

Rigor and depth *do* make a difference.

International comparative research shows that similar dilemmas in math and science teaching and learning exist worldwide, but other countries adopt practices different from those followed in the United States. The American math and science curriculum, in comparison to those of other nations, tends to cover too many topics in a superficial way. Similarly, the rigor and pace of math and science courses in the United States lags behind that of other countries.

Further evaluation is needed.

Some of the programs and policies that have not yet had a positive impact may need refinement and further implementation before we see measurable results. For example, on the issue of lowering class size, a 2000–2001 study in Wisconsin showed that limiting class size to 15 in grades K–3 yielded higher scores on basic skills for students living in poverty. However, California's 1996 Classroom Reduction Act produced no clear evidence of higher student achievement. Another study in Tennessee found sustained positive math and science results in grades 4, 6, and 8 for students who were in smaller classes in kindergarten through third grade, in contrast to students who were not.

Summary of Recent Reports

In its landmark 2001 report, *Roadmap for National Security: Imperative for Change*, the US Commission on National Security/21st Century noted "…the inadequacies of our systems of research and education pose a greater threat to US national security over the next quarter century than any potential conventional war that we might imagine…. If we do not invest heavily and wisely in rebuilding these two core strengths, America will be incapable of maintaining its global position long into the 21st century." The commission called for:

• Legislation providing: (a) incentives for students at all levels to pursue degrees in science, technology, engineering, and math (the STEM disciplines), (b) incentives for K–12 math and science teachers to commit to public school teaching for three to five years, (c) sustained professional development on the cutting edge of scientific and mathematical knowledge.

• Comprehensive statewide plans to avert the looming shortage of qualified math and science teachers through: (a) higher compensation, (b) administrative support as well as office space befitting professionals, (c) reform of the certification system, and (d) expansion of effective programs in districts with habitually low student achievement in math and science.

• Support for historically Black colleges and universities, especially those with a focus on STEM disciplines.

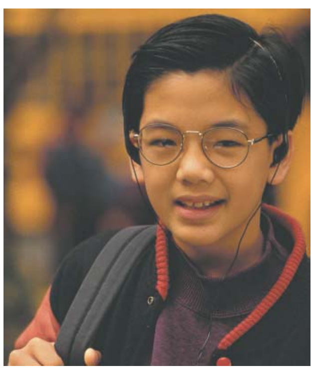
"The most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching."

The National Commission on Mathematics and Science Teaching for the 21st Century released its report, *Before It's Too Late*, in 2000. Their central message was: "the most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching." Of special concern was the devastating lack of qualified teachers in urban and rural districts; each of its recommendations included extra incentives for qualified teachers to enter and stay in low-performing districts:

• Sustain an environment of, and an expectation for, continued learning among math and science teachers through (a) summer institutes, (b) leadership training, (c) use of technology, among others.

• Increase significantly the number of math and science teachers and the quality of their preparation, as well as the equitable distribution of highly qualified talent to high-need districts though (a) recruitment incentives for first- and second-career entrants to the field, and (b) exemplary and innovative teacher preparation models.

• Improve the working environment so that the teacher profession is more attractive to highly capable people through (a) coaching and mentoring, (b) retention incentives, (c) increased salaries, and (d) new community partnerships.



The Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development released its report, titled "Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering and Technology," in 2000. They called for implementation of a national agenda that focused on increasing diversity in scientific fields, stating: "If…the United States continues failing to prepare citizens from all population groups for participation in the new, technol-

Summary of Recent Reports

ogy-driven economy, our nation will risk losing its economic and intellectual pre-eminence." At the K–12 level, the report calls for:

• Adoption and implementation of comprehensive, high-quality state standards for math and science curriculum, teacher qualifications, technological assets, assistive technologies, and physical infrastructure.

• Collection of and accountability for achievement data in school districts disaggregated by socioeconomic status, limited English proficiency, disability status, race/ethnicity, and gender.

A public-private partnership called BEST—Building Engineering and Science Talent—described its strategies in a 2002 document titled "The Quiet Crisis: Falling Short in Producing American Scientific and Technical Talent." At the K–12 level, BEST plans to:

• Identify best practices that develop and draw on the talent of underrepresented groups of students in math and science.

• Partner with interested communities to adopt or adapt these best practices.

"If…the United States continues failing to prepare citizens from all population groups for participation in the new, technology-driven economy, our nation will risk losing its economic and intellectual pre-eminence."

The Committee for Economic Development released a report in the spring of 2003 titled "Learning for the Future: Changing the Culture of Mathematics and Science Education to Ensure a Competitive Workforce." A distinguishing feature of this report is its recognition that "…improving the nation's math and science education will require change on the *demand* side… that is, the way our nation's young people regard these disciplines." It offers a series of recommendations to:

• Increase student interest in math and science to maintain the pipeline.

• Demonstrate the wonder of discovery, while mastering rigorous content in math and science courses.

• Acknowledge the professionalism of teachers to help solve the teacher shortage.

To further call attention to math and science education regarding the issues raised in these reports and the lessons that have been learned, the US Department of Education is launching a five-year initiative to improve math and science achievement. Still in the planning stages, the initiative targets three goals:

• Conduct a broad-based public engagement campaign that draws attention to the need for math and science education in our nation's schools.

• Undertake a major campaign to recruit, prepare, train, and retrain teachers with strong content knowledge in math and science.

• Develop a major academic research base to improve our knowledge of what boosts students' classroom learning in math and science.

Ten Major Findings/Recommendations Common to These Reports/Initiatives:

1. Teachers are well-intentioned, but often lack the knowledge to bring students to high levels of achievement.

2. Teachers must have sustained opportunities to increase their knowledge through formal coursework as well as rigorous professional development.

3. The unfortunate practice of assigning teachers to classes out of their area of expertise is especially common in math and science; its negative impact is greatest in high-poverty districts.

4. While recruitment of teachers knowledgeable in math and science is important, even more critical is the retention of capable math and science teachers.

5. Elementary school teachers cannot be expert in all the subjects they are expected to teach; they must have ready access to experts to complement their knowledge.

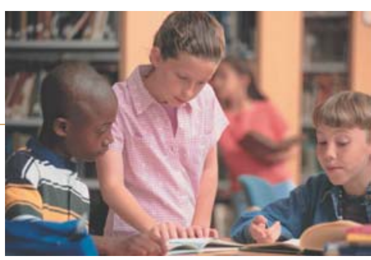
6. Talented teachers must be well compensated to keep them in the classroom, and classrooms must be well equipped to support scientific inquiry.

7. Some changes need additional state and federal investments, as the cost of doing nothing is even greater. For example, the number of math and science teachers returning each September dwarfs the number of new hires, suggesting that staff development should be a priority. Similarly, special strategies are needed for urban and rural districts, e.g., recruitment and retention enticements for qualified math and science teachers; e-learning for small, isolated schools unable to offer an array of rigorous math and science courses; and mentors to help teachers whose students are not succeeding.

8. All students should take rigorous math and science courses to prepare them for an array of career options. Students must be held to the same high expectations and have the necessary educational support, nurturing, and remediation to help them succeed.

9. Math and science standards, assessments, and curricula need better alignment, with a more coherent sequence of topics that build depth of understanding.

10. Gaining widespread public, parent, and student understanding of the importance of math and science for all students—in preparation for careers, citizenship, and social mobility—is critical.



The Math Proficiencies of College-Bound High School Seniors:

Selected Findings from an Analysis of Math SAT-I Data for the New England States

A large number of college-bound seniors with strong math skills are not pursuing science, engineering and IT fields, while women and minority students who are drawn to these fields are limited by insufficient math skills.

by W. Neal Fogg *and* Paul E. Harrington

The second half of the 1990s saw the New England regional economy enter a period of substantial job growth and sharp reduc-tions in unemployment rates, developments with a number of positive consequences for the region's workers and families. For employers, however, these developments led to labor shortages in key labor market segments throughout the region. These labor shortages became a significant constraint on the ability of the regional economy to expand output and employment levels. Labor supply problems in scientific, engineering, and information technology (SEIT) occupations led to severe labor shortage problems in a number of states in the region by the end of the decade.

Since early 2001, job losses have mounted and unemployment levels and rates have risen sharply in the region. With the onset of the national economic recession, New England's labor shortage problems in the SEIT-related fields have largely abated. Indeed, there is considerable evidence that at least during the first year of the downturn in the region a substantial proportion of the increase in unemployment was concentrated among college graduate workers—especially in information technology fields.

Despite the current adverse employment situation in New England and especially Massachusetts, concerns about long-term labor supply problems remain, especially in math-dominated SEIT fields. The low unemployment rates achieved in New England by 2000 were largely the result of very slow labor supply growth in the region. New projections of labor force growth completed by the Center for Labor Market Studies (CLMS) at Northeastern University suggest that regional labor supply growth will remain well below that of the nation as a whole—raising the specter of labor shortage problems returning once the national recovery gains strength and job growth returns to New England.[1]

Colleges and universities in New England were unable to expand the supply of new college graduates in SEIT- related fields during the 1990s. Taken as a whole, the number of students earning bachelor's degrees in these fields declined during the 1990s, despite strong labor demand conditions during the second half of the decade. A number of observers have expressed concerns that the elementary and secondary school systems in the region have been unable to produce a sufficient number of students with the interests and abilities required to complete an undergraduate degree in a SEIT-related field. In short, the educational pipeline has been unable to feed the manpower requirements of employers thirsty to expand output and employment.

In order to examine the math/science pipeline issue in greater detail, we have undertaken an analysis of the mathematical proficiencies of New England's high school seniors based on the math SAT-I test administered to college-bound students from the graduating class of 2000. The data we utilized are based on our analysis of a set of micro-data files that we purchased from the College Board and are based on our analysis of the individual demographic and test score records of over 110,000 seniors from each state in the New England region. These data thus provide the only comprehensive, standardized measure of the math skills of high school seniors in New England. Moreover, since we have obtained the data in a micro-file format, we have created a wide variety of tabulations that permit us to gain insight into a range of important factors associated with the math skills of the region's college-bound seniors. Following are some of the initial findings of our analysis.

Math SAT-1 Scores Among the New England States

Test scores on the math SAT-1 test varied by state. New Hampshire test-takers scored above their counterparts in the region, with a mean score of about 520 on the math portion of the test. Massachusetts seniors ranked second, with a mean score of 514. Maine and Rhode Island had lower mean scores of about 501. The differences in mean test scores observed between higher-scoring states like New Hampshire and lower-scoring states like Maine and Rhode Island are associated with differences in the distribution of test scores. States can have identical means on the test but much different patterns of performance around those means. That is to say that understanding the distribution of SAT scores from a policy point of view is at least as important as knowledge of the average score in each state.

Table 1:
Math SAT-I Scores in New England, by State, 2000

	Number	Mean	Standard Deviation	Coeff. of Variation
Total	110,359	511.3	113.9	0.223
New Hampshire	10,483	519.7	107.2	0.206
Massachusetts	48,964	514.2	116.4	0.226
Connecticut	28,552	510.4	117.0	0.229
Vermont	5,007	508.3	104.1	0.205
Rhode Island	6,993	500.8	110.6	0.221
Maine	10,360	500.5	104.6	0.209

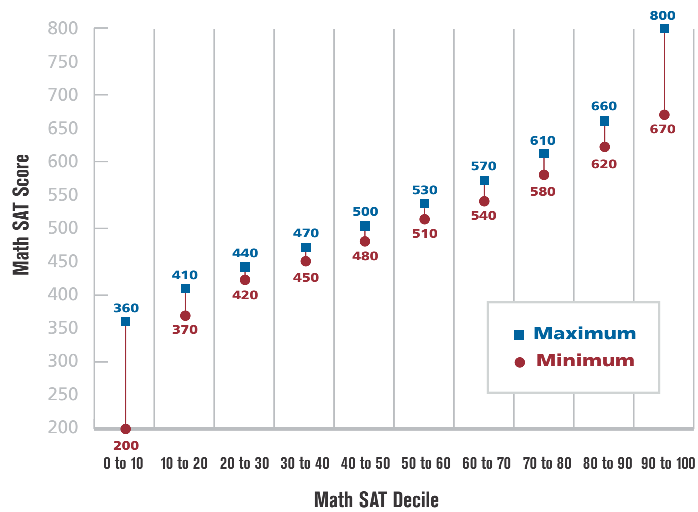
These data reveal that the mean score on the math SAT was 511.3, about the same as the overall national average of math SAT test-takers. The standard deviation about the mean is 113.9 for the region, indicating a substantial degree of variation in test scores among college-bound seniors.

In order to learn more about the distribution of math SAT-I test scores around the mean score we have sorted each of the 110,000 records of test-takers into deciles. The deciles are (approximately) equal in size and represent a rank ordering of students by their math reasoning skills. The data provided in Chart 1 further describe the math SAT test score distribution. The chart gives the minimum math SAT score and the maximum score associated with each decile.

An examination of the distribution of test scores in each state in the region reveals the way that differences in the distribution of test scores can help explain state mean score differences.

The data provided in Table 2 reveal that only 16 percent of New Hampshire students scored in the bottom 20 percent of the regional test score distribution, while Maine had 21 percent and Rhode Island 22 percent. In contrast an important part of the explanation of relatively lower mean scores for Maine and Rhode Island is the lower shares of students scoring at the high end of the skills distribution. Maine had only 15 percent of its students earn a score of 620 or better on the test (the score that would place them in the top 20 percent), while Rhode Island had just 16 percent of its test-takers score at this level or above.

Chart 1:
Minimum and Maximum Math SAT Score in New England, by Decile, 2000



The minimum and maximum scores define the cut-offs or boundaries for each of the deciles. For instance, the second-lowest decile is defined as persons who scored between 370 and 410 on the math SAT.

Table 2:
Mean Math SAT Scores and Share of Students Scoring in the Top Quintiles and Bottom Quintiles of the Score Distribution

	Mean Score	Bottom 20%	Top 20%
New England	511.3	20	20
Connecticut	510.4	21	20
Maine	500.5	21	15
Massachusetts	514.2	20	20
New Hampshire	519.7	16	20
Rhode Island	500.8	22	16
Vermont	508.3	20	16

Part of the reason New Hampshire students had an average score well above those of Maine and Rhode Island is associated with differences in their score distributions. New Hampshire's score premium is clearly associated with below-average shares of very low scoring students.

States seeking to improve average skill levels may find that focusing resources on those at the very bottom of the skills distribution may have the greatest ability to improve test scores. In contrast efforts to increase the number of students with sufficient math skill to enroll in and complete an engineering program would not focus at all on those at the bottom of the score distribution. Instead, such efforts would likely target students with scores that are above average, but not sufficiently high to assure success in a rigorous, math-intensive course of study.

Gender Differences in Test Scores and Intended Major Fields of Study

For much of the 20th century, men heavily dominated higher education. Over the past few decades, however, women's college-enrollment levels have skyrocketed. In fact, by the mid-1980s, women earned more than half of all bachelor's degrees in the nation. Today the proportion of women enrolling in college substantially exceeds that of men. The findings in Table 3 raise an important question about the impact of gender on enrollment in SEIT-related major fields of study. For the high school class of 2000, about 59 percent of boys and 66 percent of girls, nationally, enrolled in a post-secondary education program. In Boston the differences are greater still, with 143 females enrolling in post-secondary program for every 100 boys enrolled. Rising gender differences in college enrollment rates, combined with large math score gaps, may contribute to the enrollment problems in SEIT-related fields of study at the post-secondary level. As females make up a higher share of the entering class each year and have, on average, lower math proficiencies, we would expect that enrollments in fields of study that require strong math skills would decline. Indeed, this has been the case regionally and nationally in SEIT fields.

In order to examine this issue in greater detail Table 4 considers data on the distribution of male and female test-takers by quintile. High school seniors who have strong math skills intend to major in a wide array of fields. However, intended majors do vary systematically by the level of a student's math proficiency. Chart 2 suggests that the likelihood of a student majoring in a SEIT-related field of study depends on the level of their math skills. However the data suggest that the connection between majoring in a SEIT field and rising math scores is not very strong through the first three quintiles of the distribution. In fact as scores rise from the bottom of the distribution (less than 420) up to the middle quintile

Table 3:
Math SAT-1 Test Scores in New England, by Gender, 2000

	Number	Mean	Standard Deviation	Coeff. of Variation
Female	58,490	495	110.2	0.222
Male	51,869	529	115.2	0.218
Total	110,359	511	113.9	0.223

About 6,600 (roughly 13 percent) more female high school seniors took the math SAT-1 in 2000 than did their male counterparts. Female test-takers had mean scores on the math test of 495, while males earned a mean score of 529, a gap of 34 points or nearly one-third of standard deviation.

Minimum score for success...600

Recently, we worked with Alan Soyster, dean of Northeastern University's College of Engineering, to determine a rule of thumb concerning the minimum math SAT-1 score thought necessary to successfully matriculate in a bachelor's degree engineering program in the region. Dean Soyster contacted some of his counterparts around the region to gather their impressions of the score thought necessary to succeed (not simply be admitted) in their engineering program. The consensus around the region was that a score of 600 was needed to ensure a strong probability of success. A more formal study conducted at Purdue University came to a similar conclusion, suggesting that a math score in the 600 to 620 range was needed to ensure a high probability of success in a rigorous undergraduate engineering program.

Assuming that a score of 620 on the math SAT-I is needed to succeed in an engineering course of study, the low proportion of females scoring in the top quintile suggests that as females become a larger share of the entering freshman class, the proportion of that class possessing the math skills needed for success in the SEIT-related majors will decline. Thus it appears that not only do gender gaps in the average math SAT-1 score matter, but large differences in the score distributions also appear to contribute to the enrollment problem.

Table 4:
The Distribution of Male and Female Math SAT-1 Test Takers in New England, by Quintile

	Males	Females	Ratio of Males to Females
Top Fifth	25%	15%	1.67
60th-80th	23%	21%	1.10
40th-60th	20%	21%	0.95
20th-40th	16%	20%	0.80
Lowest Fifth	16%	24%	0.67

Data reveal very large gender differences in the fraction of students who scored in the top fifth of distribution. One quarter of all male test-takers earned a score of 620 or higher on the math SAT-I test while only 15 percent of females had a score that placed them at the top of the distribution. This finding is of particular importance in assessing enrollment problems in SEIT-related fields of study.

(480 to 530), the increase in the share of students intending to major in SEIT fields does not rise very rapidly.

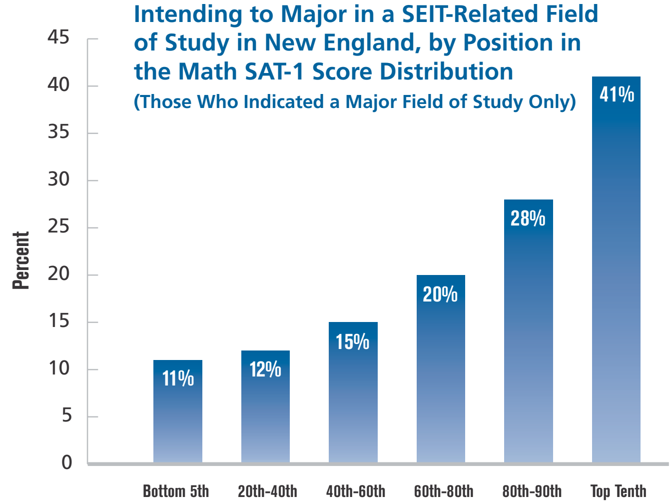
Student interest in SEIT-related fields rises sharply at the top of the math score distribution. Approximately 28 percent of the students who score between the 80th and 90th percentiles (620 to 660) indicate that they intend to major in a SEIT-related field. Students scoring in the top 10 percent of the math score distribution are most likely to major in a technical field. More than 40 percent of students with scores in the top 10 percent of the distribution (670 or better) intend to major in a SEIT field of study.

While math scores are an important predictor of the likelihood that a student will major in a SEIT field of study, gender appears to play an equally important role. Table 5 provides data by gender on the intended major field of study of students who scored in the top quintile of the math score distribution. The data reveal sharp disparities between males and females with strong (620 or better) math SAT scores in their intended major field of studies.

A closer look at the table reveals that the gender disparity was greatest in the computer science field, in which males were nine times more likely than females to major. The discrepancy was also quite large in the engineering fields; males were 3.5 times more likely to say they intended to major in the field than were equally math-proficient females.

These findings reveal that simply improving the math scores of females will be insufficient to raise the proportion of young women who enter SEIT fields. Strategies designed to encourage young women to enter these fields need to be developed along with efforts to raise math scores in order to increase the female share of students in the technical fields of study.

Chart 2:
The Proportion of College-Bound Seniors Intending to Major in a SEIT-Related Field of Study in New England, by Position in the Math SAT-1 Score Distribution
(Those Who Indicated a Major Field of Study Only)



Only about 11 percent of college-bound students in the bottom quintile of the distribution say that they intend to major in a SEIT-related field. This rises to just 12 percent for the second-lowest quintile and to 15 percent for the middle quintile. The proportion begins to rise substantially only as we reach students in the second-highest quintile--with scores ranging between 540 and 610. About 20 percent of these students indicate that they will major in a SEIT-related field.

Table 5:
Intended Major Field of Study of Male and Female Test-Takers in the Top Quintile of the Math SAT-1 Distribution, 2000

	Males	Females	Ratio of Males to Females
Total SEIT	58%	18%	3.2
Engineering	28%	8%	3.5
Computer Science	18%	2%	9.0
Math	3%	3%	1.0
Physics	6%	5%	1.2
Biology	8%	17%	0.47
Social Sciences	21%	31%	0.68
Education	4%	11%	0.36

Overall, 58 percent of high-scoring males said they intended to major in a SEIT-related field, while only 18 percent of high-scoring females said they were interested in majoring in a technical area. Thus, among the most math proficient students, males were 3.2 times more likely to say that they intended to major in a SEIT-related field than were females.

Race and Ethnic Differences in Test Scores and Intended Major Fields of Study

Over the past decade the race/ethnic composition of the school-age population in New England has changed considerably, with a growing proportion of high school–age students being members of race/ethnic minority groups. In the future, the region will become increasingly dependent on these individuals to supply labor in a wide array of occupational areas including SEIT-related fields. The level of math proficiency of the school-age members of these minority populations will become an important determinant of the region's ability to remain an international center of technology, generate strong economic growth, and staunch the region's growing problem of income inequality.

Table 6 provides data on the mean math SAT-I scores of college-bound seniors in the class of 2000 by race and ethnicity.These scores reveal large race/ethnic disparities in math reasoning skills. Moreover, they suggest that access into SEIT-related fields of study (and ultimately access into related occupations) is severely limited for Black and Hispanic students. The average Black student scores nearly one standard deviation below the average White student and more than one standard deviation below the average Asian, college-bound senior.

Within each of the race/ethnic groups included in the table, substantial variation in scores occurred. The standard deviation for each group exceeded 100 points. Thus it is important to examine the underlying distribution of the math scores to better understand the nature of the observed disparities in the means across race/ethnic groups.

The findings provided in Table 7 reveal extraordinarily sharp differences in the distribution of math test scores across race/ethnic groups in the New England region. The findings on Hispanic and, even more so, Black students' test scores paint a powerful and disturbing picture. More than one half of all Black test-takers earned scores that placed them in the bottom fifth of the basic skills distribution. Among Hispanic students this proportion was 42 percent. This means that Black students were nearly five times more likely than White students to earn a score of 410 or lower on the math SAT. Hispanic students were about four times more likely than White students to earn a score that places them at the bottom of the skill distribution.

These findings mean that the gap between the math reasoning skill levels thought needed to succeed in SEIT-related fields of study and the actual skill levels of Black and Hispanic students in the New England region is enormous. Moreover, the data on the distribution of the scores reveals that marginal changes in test scores will have little impact on the share of Black and Hispanic students who score in the top fifth of the skill distribution. If we were able to double the share of Black students scoring at the top of the math distribution, this would only increase the number from about 200 to 400.

For the overwhelming share of Black and Hispanic college-bound seniors there is little chance of studying in a SEIT-

Table 6:
Math SAT-1 Test Scores in New England, by Race/Ethnic Group, 2000

	Number	Mean	Standard Deviation	Coeff. of Variation
White, Non-Hispanic	79,988	520	106.7	0.205
Black, Non-Hispanic	4,514	419	104.5	0.249
Hispanic	3,928	450	120.8	0.268
Asian, Pacific Islanders	4,062	545	128.1	0.235
Other	17,867	501	125.7	0.251
Total	110,359	511	113.9	0.223

Asian college-bound seniors had the highest mean math scores of any group included in the table. Their average score of 545 was sharply above the region-wide score of 511. Non-Hispanic White students had the second-highest score, averaging 520 on the math test, somewhat above the average score for the region. Non-Hispanic Black and Hispanic scores were well below the mean scores for the region, at 419 and 450, respectively.

Table 7:
The Distribution of Math SAT-1 Test-Takers

	White Non-Hispanic	Black Non-Hispanic	Hispanic	Asian/Pacific Islanders
Top 20th	20%	4%	11%	32%
60th-80th	24%	10%	13%	21%
40th-60th	22%	14%	14%	16%
20th-40th	18%	21%	20%	14%
Bottom 20th	11%	51%	42%	17%

Asian/Pacific Islander college-bound seniors were most likely of all the groups to score in the top 20 percent of the overall test score distribution. Nearly one in three Asian test-takers achieved a math score of 620 or better. Among non-Hispanic White seniors this proportion was 20 percent. Only 11 percent of all Hispanic test-takers had math SAT scores that would place them in the top quintile. Hispanics were about one half as likely as non-Hispanic Whites to score 620 or better and one-third as likely as Asian students to achieve this score.The proportion of Black seniors scoring in the top quintile was only 4 percent. In fact, only slightly more than 200 Black seniors in the entire New England region achieved math SAT-I scores of 620 or greater.

related field. Their low math scores preclude study in SEIT, biology, and some health sciences, as well as selected business and social sciences. In turn, this means that at the age of 17 or 18, these youngsters have very poor odds compared to White and Asian college-bound seniors in gaining access to the best sets of employment opportunities in the American economy.

Table 8:
Intended Fields of Study of College-Bound Seniors in New England, 2000

	White Non-Hispanic	Black Non-Hispanic	Hispanic	Asian/Pacific Islanders
Humanities	14%	10%	11%	10%
Business	18%	24%	25%	28%
Social Sciences	27%	31%	29%	15%
Education	16%	9%	11%	5%
Biology	8%	5%	5%	8%
Computer Science	7%	10%	9%	17%
Engineering	8%	9%	10%	15%
Math	1%	0%	1%	1%
Physical	2%	1%	1%	2%
SEIT Share	18%	20%	20%	35%

While Black and Hispanic college-bound seniors have much lower math reasoning test scores, they report the intention to major in a SEIT-related field at about the same rate as White students. Black and Hispanic college-bound seniors who expressed an intended major field of study reported that they intended to major in a SEIT-related field one fifth of the time—a proportion slightly higher than that for non-Hispanic White students. This finding is indeed surprising, given their relatively low math scores.

Our earlier discussion revealed a fairly strong correlation between math SAT reasoning skills and intentions to major in SEIT-related fields. We found that students scoring in the lower quintiles of the math distribution were much less likely to report that they intended to major in a SEIT field relative to students with scores in the upper quintiles. More than 85 percent of Black students and 75 percent of Hispanic students scored below the 60th percentile. This would suggest that Black and Hispanic students would indicate that they would major in SEIT-related fields of study at substantially lower rates than their non-Hispanic White counterparts. Yet, the data in Table 8 reveal that these students intend to major in these fields at the same rate. A dissonance exists between the actual math skills/intended fields of study, and the career aspirations of Black and Hispanic students. ❖

1. Neeta Fogg, Gary D'Entremont and Paul Harrington, "Labor Force Projections in New England 2000 to 2015," Center for Labor Market Studies, Northeastern University, February 2003.

Report from the Front Lines:

A Primer for Business About a Teacher-Centered Math, Science, and Technology Strategy

Any long-term success in sending more K–12 students into the engineering pipeline ultimately centers on teachers, particularly at the elementary and middle-school levels. Therefore, business should focus its efforts on developing and supporting teachers so as to enhance math acheivement.

by Phil Primack

Brian was beaming. The fourth grader and a group of classmates were working out a wiring problem with Al Scarpa, a retired Raytheon engineer who regularly volunteers his hands-on experience to teacher Patricia Eastman's Woburn classroom. "I like this class because you learn that science can be fun and not boring," said Brian. "We're allowed to take apart things like an electric motor and see how they work and learn about electricity. I didn't like science before, because it was boring."

Sally, too, has become more interested in science. "This is kind of hard, but I like hard stuff," she said. So does Brian. He said he wants to go to MIT "so I can learn more about science and technology. I want to become an electrical engineer."

Such words are music to the ears of researchers, policymakers, educators, economic development experts, and technology-sector managers, all of whom worry about the engineering pipeline problem: Not enough American students are entering math, science, and technology (MST) study tracks.

"This isn't just about the labor pipeline, it's about feeding and sustaining an innovation economy."

Neither the issue nor the concerns are new. As the preceding report by The Business Roundtable suggests, there are innumerable studies, reports, articles, and Web sites about the need to interest more American K–12 students, especially girls and minorities, in MST. Nor does the issue lack a wide range of on-the-ground attempts at solutions. Pat Eastman obtained technical materials for her class through the Engineering in Mass Collaborative (EiMC), a partnership of Bay State companies, universities, and government that offers a range of MST activities for students, teachers, and corporations to advance understanding about—and interest in—engineering. A plethora of programs share similar goals. Some are national, such as former astronaut Sally Ride's Imaginary Lines, whose goal is "to provide support for all the girls who are, or might become, interested in science, math, and technology". Others are smaller, run by individual states, universities, corporations, museums, and other nonprofit organizations.

Less easy to identify and quantify—but arguably more important—are efforts such as Pat Eastman's, where people are working hard, creatively, and often alone, in schools and

Report From the Front Lines

classrooms across the nation to make math, science, and technology studies more accessible, meaningful, and attractive.

In short, we have identified the issue and we appreciate its importance. We have best practices that effectively deal with the problem, but we have failed to integrate all the research and all the what-works examples into a coherent strategy. "We have a lot of these very good programs going on, but they need to be scaled up," said Analog Devices founder and chairman Ray Stata, who also co-chairs EiMC. "They never reach the critical mass where they are institutionalized into the system."

"From the evidence at hand, we are not doing the job we can—and should—do in teaching America's children. They are simply not world-class learners when it comes to math and science."

Institutionalizing that critical mass obviously matters to today's young students who, as tomorrow's scientists and engineers, are the linchpin of a sustained innovation economy. But it is also in the clear self-interest of technology and other engineering-driven businesses across the Commonwealth to become more proactive in shaping an MST strategy. Painful as today's economic conditions are for both industry and policymakers, this down time offers an opportunity to develop such a strategy now, before the next cyclical skilled-labor shortage.

To help offer real context to the BRT overview, we asked a range of people directly linked to the pipeline issue in Massachusetts to talk about key pieces of a systemic approach—and what it will take to get there. They share an overarching premise: Any long-term success in sending more K–12 students into the engineering pipeline ultimately centers on teachers, particularly at the elementary and middle-school levels.

While this paper has a Massachusetts focus, its applications are national. Programs that succeed in a technology-oriented state like Massachusetts offer models for other states. And the work of EiMC (described in more detail below) is a model for how other states and the nation can bring together the public- and private-sector players who are the key to effectively dealing with the pipeline issue.

We interviewed, in person and via e-mail, teachers who have participated in EiMC and other MST programs and some who have not. We spoke to young students like Brian and Sally, academic and private-sector experts, MST program directors, and others. We asked them what makes good MST teachers and attracts them to the job, what MST curricula and teaching methods inspire young students, and how to retain such teachers, despite relatively low pay and even lower public recognition for the critical jobs they do.

"You can't just hand out a pamphlet about this or that program or conduct a few field trips," said EiMC founder Krishna Vedula, dean of the Francis College of Engineering at the University of Massachusetts Lowell. "We must have a robust infrastructure for the best practices. We need a professional math, science, and engineering network throughout the state. There are organizations for teachers, for companies, for administrators and others, but there must also be regular connections between them. If you don't have enough of the right people in the right places worrying about the details, then even the best practices can fail."

The stakes are clear: a too-narrow pipeline is a direct threat to the Massachusetts economy. As EMC Corp. Executive Chairman Michael Ruettgers said on CBS Market Watch, "Students form the seedbed of our economy's future. It's time for our nation to replenish education's seed stock."

For business, the motivation to improve MST capabilities in our schools extends well beyond the need to assure a supply of engineering and other technical talent. With its high housing and other costs, Massachusetts is already a tough place for luring talent. The quality of the state's K–12 system, especially its capacity to meet the educational expectations of scientists and engineers for their Bay State children, can make the difference in firms' ability to attract and retain critical employees.

"We will simply not be able to keep creating the innovations we need, if Massachusetts doesn't have more than its fair share of people trained in science and engineering," said John F. Hodgman, EiMC Board member and Howard P. Foley Professor for High Tech Workforce Development at UMass Lowell. "This isn't just about the labor pipeline, it's about feeding and sustaining an innovation economy."

Build on the Progress to Date

As the BRT overview confirms, many well-researched studies and national conferences have already analyzed and documented the extent and seriousness of the MST teaching problem. Back in 2001, for example, the Council on Competitiveness released "The Innovation Imperative, which focused on workforce training and student education issues. The council put it this way: "From the evidence at hand, we are not doing the job we can—and should—do in teaching America's children. They are simply not world-class learners when it comes to math and science."

The "Math Proficiencies" paper that precedes this report demonstrates this. Among other things, the paper reveals continuing gaps in math SAT scores based on race and gender. Perhaps even more disturbingly, the paper finds an enormous disparity between males and females—even among those who do well in math—when it comes to a desire to major in science- and engineering-related fields.

Again, a thousand best practices have attempted to address this serious issue. Take, for example, this matter of interesting more girls and minorities in MST studies and eventual careers. A Google search using these search terms: [girls + school + science + engineering] yielded a staggering 214,000 hits. Some are linked to programs sponsored by universities and corporations across the nation to help advance K–12 MST education. Some are prominent, such as programs by the National Science Foundation and the National Academy of Engineering. Others reveal the tip of a cyber-iceberg of lesser-known but seemingly interesting programs, such as:

- **GEMS** (Girls in Engineering, Mathematics, and Science), "a collaborative effort between school and business to encourage girls' interests and competencies in science, mathematics and technology" (www.eot.org/TTF/Access/acc06-gems.html).

- **Digital Sisters**, "focuses on technology empowerment programs, particularly for young girls and women of color" (www.digital-sistas.org).

- **The Technology Leadership Institute** (TLI), a federally funded project aimed at "building a digital community focused on the integration of technology into teacher preparation programs" (www.tli.unt.edu).

Though our interviews confirmed a clear race-gender gap in MST studies—and in subsequent technology-sector employment—many also suggested that rather than special programs, a rising-tide response was more appropriate: the best solution, they said, is to improve MST for *all* grades and groups. "I'm not sure that we need special programs just for girls and minorities," said one high school physics, engineering, and science teacher. "I'm always a bit leery about singling out one group or another .... We need to do more in general to motivate students in MST."

"Can schools offer programs that are sensitive to girls without shortchanging boys? If we can't figure out how to do that, we'll never get to the most significant part of the problem."

Others did call for special attention to the gender-and-minorities MST gap. "With girls now making up a large percentage of college-bound students, we need to better understand the dynamics that affect girls taking MST courses and eventually choosing those fields," said Hodgman, former president and chief executive of the Massachusetts Technology Development Corporation. "Can schools offer programs that are sensitive to girls without shortchanging boys? If we can't figure out how to do that, we'll never get to the most significant part of the problem."

In Massachusetts, efforts to improve overall school performance continue. MassInsight Education, for example, has formed the Math Achievement Partnership of state leaders, the business community, higher education, and local school districts to deal with the persistent problem of low math achievement in grades K–12.

Report From the Front Lines

Engineering in Mass Collaborative: A Best-Practice Template

In 1997, EiMC was founded "to plant the seeds of tomorrow's workforce." Its creation was triggered by the startling fact that the number of degrees awarded in engineering in Massachusetts had fallen by 37 percent between 1987 and 1996. Though there has been a slow increase since then, the Massachusetts economy will again face a crisis: not enough skilled workers in math and science when the economy recovers. This is, in large part, because not enough talented high school graduates are drawn to science and engineering careers.

More than 300 public- and private-sector members, including nearly 100 companies from Fidelity, Raytheon, and Analog Devices to small start-ups, now participate in EiMC efforts to increase K–12 student interest in and preparation for such careers. EiMC is the closest Massachusetts has to a central clearinghouse for best practices in MST teaching activities.

Founder Krishna Vedula uses a farming metaphor to explain EiMC's philosophy. "Math and science teachers are key to what we call our 'planting' model, the essence of which is exposing students in K–12 to potential careers in science and engineering through their curriculum and encouraging those who show an aptitude for and interest in such careers," he said. "Teachers need to sew the seeds and nurture the fledgling engineer and scientist plants. However, these teachers can acquire the skills they need only with help from engineers and scientists in industry and higher education."

EiMC, which now has a database of about 2,000 names, offers such help through a number of programs and approaches. (See www.eimc.org for more information.) EiMC also hosts semiannual meetings and a range of workshops to identify, assess, and promote specific best practices and their outcomes. EiMC best practices fall into these major categories:

Professional Development for Teachers

Faculty from science and engineering schools work with engineers from industry and with outstanding middle- and high-school teachers to develop and conduct courses for K–12 math and science teachers. The goal of these courses is to help teachers develop curriculum modules that use engineering context and real-world applications. Other EiMC best practices focus on making sure that new teachers are properly prepared in relevant math and science content and pedagogy.

STEMTEC
The Science, Technology, Engineering and Mathematics Teacher Education Collaborative (http:/ k12s.phast.umass.edu/~stemtec). This five-year project, funded by the National Science Foundation, is a UMass and Five College/Public School Partnership. STEMTEC assures that the participating colleges have courses that offer the necessary content while modeling the kind of student-active learning that has proven successful in the classroom.

The Center for the Enhancement of Science and Mathematics Education (www.cesame.neu.edu) is a nonprofit, K–12 mathematics- and science-education reform organization supported by the NSF, Northeastern University, and other organizations. Its Teacher Innovation Program helps classroom teachers create and implement innovative teaching strategies.

PTC Corp.'s Design & Technology in Schools Program (www.ptc.com/go/schools) provides educators with the company's design software programs, affordable teacher training, instructional materials, and other resources that are often too costly for school systems to buy. PTC has offered its software program and instructional materials free to the state's 600 middle and high schools.

Boston University's CityLab (www.bumc.bu.edu/Departments/HomeMain.asp?DepartmentID=285) has involved more than 20,000 students, about one third of whom are from Boston public schools, in its hands-on, discovery-oriented activities since 1992. About 1,500 teachers have attended CityLab workshops.

Summer Programs for Teachers

Math and science teachers are offered stipends for summer externships in industry to help them experience the real world of engineering. Orientation and follow-up ensure that the teachers receive assistance in using their summer experiences to motivate their students to better understand engineering careers, as well as the importance of math and science to support these careers.

Teachers in Industry (TI-IN) program, pioneered by Charles River School-to-Career Consortium (www.newton.mec.edu/tiin/crc/index.html), was founded in 1997 to help teachers understand the work environment and job skills required by employers. In a six-week summer externship, teachers work on real-world projects assigned by their sponsors. They are expected to take knowledge and insight back to their classrooms.

Summer programs for K–12 students

Summer camps organized by EiMC motivate students to become interested in science and engineering careers. The focus of these camps is to demonstrate the fun of hands-on engineering and to emphasize the relevance of their math and science lessons.

UMass Lowell Design Camp (www.designcamp.org) offers hands-on science and engineering workshops for students in grades 5 through 10. The courses, conducted by K–12 math and science teachers, engage the students in interesting and challenging projects, such as designing a bedroom security system and making their own stereo speakers. Support from Raytheon has been key to the program's success, leading to an NSF grant to offer AfterSchool "camps" at UMass Lowell.

Camp Reach, at Worcester Polytechnic Institute (www.wpi.edu/Admin/Diversity/Girls/Reach), is a summer residential program for girls in Massachusetts who have completed sixth grade and are interested in learning more about careers in engineering and technology. The program includes hands-on workshops, a design project for a community organization, field trips, recreational activities, and follow-up programs during the academic year.

The Biogen Community Laboratory (www.biogen.com/site/content/community/biogen_community_lab.asp) offers students hands-on experience in science and biotechnology at a state-of-the-art teaching lab in one of the firm's Cambridge research buildings.

Volunteer engineers in K–12

More than 300 retired engineers are currently engaged with school districts across the state, offering hands-on knowledge to encourage more students toward science and engineering careers. Northeastern University pioneered this program ten years ago, and it is now supported by industry contributions. Retired engineers receive training and are provided with the support structure to be effective in assisting K–12 teachers with science and engineering experiments in their classrooms.

RE-SEED (Retirees Enhancing Science Education Through Experiments and Demonstrations) (www.reseed.neu.edu), is a Northeastern University program that prepares engineers, scientists, and other individuals with science backgrounds to assist middle-school science teachers in teaching the physical sciences. Participants volunteer in classrooms once a week for one academic year. RE-SEED began in 1991 with six volunteers. More than 400 RE-SEED volunteers have since worked in schools in about 100 communities throughout the country, giving more than 400,000 hours of their time.

The Retirees' School Volunteer Association (www.rsva.org) is a similar program initiated by retired engineers from Raytheon. RSVA serves 18 communities with 30 active volunteers and technical staff who assist and enhance K–12 classroom education.

Women and minorities in engineering

This program is built on the conviction that encouraging women and minorities in engineering is found in all the best practices promoted by EiMC. Examples of programs that have participated in EiMC workshops and are effectively emphasizing women and minorities in engineering are found at WPI (as part of the Worcester Schools Pipeline Program), at Wentworth Institute of Technology (as part of the Mass Pre-Engineering Program), at UMass Amherst (as part of the UMA Minorities in Engineering Program), at UMass Lowell (as part of the Women in Science and Engineering Program and the Lawrence Prep Program), and at Quinsigamond Community College (as part of the Women and Minorities Program).

Girls Get SET for Life: Science, Engineering, and Technology (www.engineering.tufts.edu/ggs/index.html) is sponsored by the Science Discovery Museum in Acton and the Tufts University School of Engineering and funded by the Lucent Technologies Foundation. Its goal is to promote interest and aptitude in science, engineering, and technology in teams of middle-school girls by producing exhibits to be displayed in the museum.

Report From the Front Lines

Make MST Fun

We have EiMC and other best-practice examples of solutions. What will it take to translate anecdotal best practices into a teacher-centered MST strategy?

Afifth-grade student in Lowell's Wang Middle School summarized the key to effective MST teaching, as she and her classmates worked out ways to wire bulbs to a tin cap so they would light up when the can was tilted. "Teachers can't just put something on the board and then make us sit there and write it down," said the girl, whose EiMC after-school program takes place in a UMass Lowell classroom with a hand-painted sign that says "Future Engineers Center." "Teachers have to make math and science more fun and interesting. See my backpack over there? There are four books in it, and they're all boring."

These students were not bored. Boys and girls, a full palette of races, they were the dream image of the Bay State's future technology workforce. But reaching the goal won't be automatic, or easy, or without costs. "In a program like this, we're able to get a high level of engagement from the kids," said Doug Prime, founder and director of Design Camp and a UMass Lowell graduate and former junior-high teacher who now advises UMass on K–12 science and engineering education. "We have the materials we need, and we have two teachers working with 20 kids. But compare this to the life and reality of a regular schoolteacher. Too often, our schools follow the factory mass-production model, which is to do things in the fastest and most economical way possible."

Programs such as EiMC help expand that model, but they alone cannot change teaching paradigms and practices. Interviewees called for a coordinated MST strategy to better integrate programs that advance interest in MST studies—from field trips to hands-on learning activities and design camps—into regular classroom curricula. Teachers and others said they need a central repository for information, for sharing best practice methods, for learning about innovative programs and curricula, and just to learn about one another.

"The biggest problem with science education is that many elementary teachers do not understand science."

Develop "Science Minds" Early

Not that long ago, conventional wisdom held that if you wait until high school, it is too late to interest students in MST. The too-late point soon became middle school. Now elementary schools have become the focus. The consequences of poorly prepared elementary school teachers are direct and indirect. "To motivate students to be science, math, or engineering majors, they need early exposure," one high school physics teacher told us. "Many students are lost to these fields in elementary school, where the teachers are often science- and math-phobic, passing their phobias along inadvertently to their students."

A teacher who has taught high school math, science, and engineering for nine years added: "The biggest problem with science education is that many elementary teachers do not understand science. Kids can get misconceptions from misinformed teachers, but more importantly, kids in elementary grades do not develop science minds and do not begin to see the connections across science disciplines…I hear more about inquiry in elementary school, and that's good. But until we get teachers in the early grades who really understand science, facts will just be facts. They won't lead to a basic understanding of the physical universe, which, after all, can be fairly well understood with just a few concepts."

Boston Museum of Science Director Ioannis Miaoulis said part of the challenge is to help teachers of traditional elementary and other school lessons to recognize and explain technology relevance to young students. "Many, many teachers already do [MST] activities, but they don't call it engineering," said Miaoulis. "They call it art, or design. We need to approach not only technical education teachers but also art teachers and others who already do a lot of hands-on activities. At the elementary-school level, we should be approaching any teacher interested in building things."

Another problem is that MST instruction varies not only by school district but within individual systems. As one fifth-grade teacher said, "I learn best from visuals, and I know that kids love experimenting and getting messy, no matter what age. The hardest thing for a teacher is to learn that they

don't have all the answers, but now I love working out problems together with the kids...Down the hall, though, the teacher is much more into the traditional teaching method, with lots of lecturing and note-taking. Science teachers (in higher grades) tell me that they can always tell which students come from which classroom."

Several teachers saw a complete disconnect between middle- and elementary-school approaches. "I don't even know many elementary teachers," said one. "I don't have even a clue about how they approach science. I think reading and writing and math drive the curriculum, and science and social studies sort of just happen. At the least, elementary-school teachers need to start exposing kids to some methodology, to some thinking process of prediction and observation."

EiMC Recommendations:

• "Elementary-school teachers must be more rigorously screened and prepared [in MST]," said Donald Pierson, dean of the UMass Lowell Graduate School of Education. School systems "should be much more selective with the elementary teachers they hire," insisting that they have "a strong, balanced profile," including in MST.

• Traditional, hands-on elementary-school exercises should be conducted in a way that points out MST applications—and non-MST teachers need to be made more aware of such applications.

• Greater coordination is needed between elementary school curricula and activities and those at middle grade levels and above. "We should be putting a seamless plan in place," in which districts coordinate both their MST curriculum and professional development, according to Chris Martes, executive director of the Massachusetts Association of Superintendents of Schools.

Tying Field Trips to Frameworks

While encouraging field trips to places such as the Museum of Science and the New England Aquarium, a number of those interviewed expressed concern that such trips lack context in an ongoing curriculum. "Bringing in speakers from a company or these one-day trips may keep the teachers and students happy, but the learning effect is *de minimus* unless you get the kids' attention for a prolonged period," said Ioannis Miaoulis, former dean of the Tufts University School of Engineering and now the director of the Boston Museum of Science.

Teachers generally agree, but they cite curriculum constraints and other pressures that leave them with little time or flexibility to tie the field trips more comprehensively into classroom work. "Look, I feel I'm doing well just to organize a trip to the Museum [of Science] every spring," said one frustrated fifth-grade teacher. "When we get back to school, we're already behind in what I'm supposed to be teaching under the frameworks."

The key, our respondents said, is to plan field trips or class visits as part of the ongoing MST curriculum. Field trips can and should be entertaining, but they should not be seen as an exception to the academic experience. As Miaoulis noted, "These efforts must be part of a comprehensive teaching effort that brings engineering concepts back to the classroom and coordinates them to the frameworks."

Needed: More Teachers, More Training

It is difficult to measure precisely how many K–12 MST teachers have sufficient academic background in their subject areas. According to some analyses, nearly 40 percent of these teachers in Massachusetts lack even a minor degree in their teaching field. Other data are more hopeful. For example, a recent survey of 43 school districts by the Massachusetts Department of Education (DOE) found that nearly 90 percent of grade 8–12 math teachers were certified to teach mathematics. But certified doesn't necessarily mean properly schooled in effective techniques for teaching, which is especially important now that Massachusetts has become the first state to require a formal engineering curriculum.

Even as policymakers grapple with ways to upgrade the skills of current teachers in a day of severe fiscal restraints, Massachusetts has to worry about how to replenish the ranks of retiring teachers with properly trained MST teachers. According to a DOE report about preK–12 technology/engineering education, there are fewer than 1,100 graduates in technology education in the entire country annually. "With only one approved program in this state, Massachusetts may not be able to provide the number of teachers it needs for teaching technology," the report claims. "If technology educators are in short supply in schools and districts, an increase is needed in the number of approved technology engineering teacher-preparation courses, in Massachusetts and elsewhere."

The problem is two-fold: not enough properly qualified and trained MST teachers in the current system, and not enough new ones in the teaching pipeline. As Wilfried Schmid, a Harvard professor of mathematics who helped draft the state's math curriculum, said in a Dec. 8, 2002, *Boston Globe* article: "Teachers are not taught enough math, and not enough students with mathematical aptitude are going into teaching."

Massachusetts education policymakers have focused more on math-related teaching issues than they have on science, in part because math is already an MCAS graduation requirement, while science is not. The math focus may also reflect a practical frustration expressed by several interviewees: While many hands-on programs make science education more attractive to young students, making math "fun" and thus interesting has proved more challenging.

Numerous studies have examined the issue of teacher supply and training. Within Massachusetts, programs in place or under development help potential and current teachers learn effective MST curriculum and teaching methods. The DOE offers summer content institutes, for example. At Tufts University, the education and child development programs are working with the College of Engineering on a master's program that emphasizes technological literacy for pre-service teachers.

"You need a new breed of teachers who have the confidence to work with and explore this material, who understand that it's OK to be learning with their students instead of just spouting information and thinking they're teaching them," said Martha Cyr, until recently director of the Center for Engineering Education Outreach at Tufts and now at WPI. The center is working with Tufts' Elliot Pearson School on a year-long technology curriculum aimed at all would-be teachers, not just those seeking MST certification. "These teachers will have an understanding of what every citizen should know about technological literacy," said Cyr.

EiMC founder Krishna Vedula envisions a string of regional "cells" across the state in which local school districts and businesses work with UMass and other academic institutions to provide professional development to current and potential MST teachers, as well as to non-traditional teachers, such as laid-off technology workers or others interested in new careers in teaching. "The challenge is to develop a number of courses that will directly tie the frameworks that the teachers have to teach to fun and exciting ways to teach math, science, and engineering," Vedula said.

EiMC Recommendations:

- Teaching colleges must place greater emphasis on preparing teachers, no matter what grade level or subject area, in the fundamentals of MST and in interesting, interactive methods of teaching.

- MST-oriented professional development programs must be more accessible to current teachers. With teachers facing growing demands on their time for MCAS preparation, along with budget cuts and other factors, districts must develop incentives and other creative ways to encourage participation in MST professional development programs.

- DOE must do more to disseminate information about the full range of professional development programs offered by public, private, non-profit, and university sources.

- DOE could develop a greater network of curriculum specialists, especially at the elementary level, to help teachers strengthen their MST backgrounds and to get more hands-on projects in the schools. Specific science and math content training should align with the frameworks for each grade level.

- Engineering schools, on their own or in collaboration with departments of education, should expand programs that encourage and prepare engineering students for teaching careers.

What Is a Good Teacher Worth?

For this paper, teachers, engineering students, and other interviewees were asked: "On a scale of 1 to 10 (1 is least respected, 10 is most respected), how do you feel society at large regards public school teachers? Scientists and engineers?" The responses were consistent: Teachers trail far behind.

"I think a great deal of people buy into that old Woody Allen line 'Those who can't do, teach.' I've seen numerous times, when a child is having some difficulty, then of course the teacher is to blame," said one high school teacher with an undergraduate degree from MIT. "I have had to deal with questions about why an MIT graduate would want to be a teacher, like there is something wrong with that."

Added an eighth-grade math teacher: "It's a shame that this is true, as without teachers there could be no scientists or engineers," and a high school teacher: "My business card says 'physics,' not 'teacher.'"

This lack of respect, whether measured by financial or other factors, is not limited to MST teachers. But given the shortage of qualified MST teachers—and the ability of the private sector to offer them far more in the way of incentives—we need more creative ways to attract and retain talented individuals for the K–12 MST classroom.

"People give teachers tons of respect, but no one wants to be one," said one respondent. MST teachers hear regularly—especially when the technology sector is booming—about their importance to the economy and society at large, but they labor under the pressures of the changing frameworks, MCAS, and other factors.

Many well-trained MST teachers know that they can make far more money in the private sector than in the classroom, especially in strong economic times. This has caused some to advocate higher pay for MST teachers. "Higher salaries for all teachers may sound more equitable and politically palatable," EMC's Michael Ruettgers wrote in *The Boston Globe*. "But let's get serious about the solution. Only a differentiated pay scale for math and science teachers would allow public education to compete for people who command far higher salaries in the private sector. We also need to adopt simple and expedited alternative certification requirements to allow retired technical professionals to teach math and science."

Tight budgets, as well as collective bargaining agreements, make it difficult to pay MST teachers more than others, let alone increase salaries significantly for all teachers. But other steps can be taken to make teaching more effective and to give teachers better support as they try to make MST studies more interesting and effective.

"You need a new breed of teachers who have the confidence to...explore this material, who understand that it's OK to be learning with their students."

Getting Guidance Counselors into the Loop

The focus of many MST education programs has been on teachers. There is a need for middle-school and high-school guidance counselors to be more active in programs that encourage students, especially girls and minorities, to consider MST studies and careers. Fortunately, there are programs for guidance counselors at places such as Worcester Polytechnic Institute and the Museum of Science. It's a start.

EiMC Recommendations:

- At the least, give MST teachers the supplies and resources they need. Several teachers told of paying for lab equipment, materials, and other course materials out of their own pockets. One scrounges for teaching tools at the local dump. Districts should develop a streamlined, fast-response system by which teachers can acquire modest funds for MST efforts.

- Work with organizations such as EiMC and local technology firms to secure summer placements with stipends for MST teachers, who gain not only extra income but also invaluable experience to take back to the classroom.

- Encourage MST teachers and students to enter out-of-school competitions, events, and other activities that build hands-on teaching experience.

- Publicize—within the school and to local media—the success of MST teachers and students in MST activities, and publicly recognize teachers for their participation in professional development and other efforts.

It's TIme for Business to Rachet Up Involvement

Massachusetts companies and nonprofit organizations already play an important role in bolstering MST efforts. Corporate programs provide teaching tools and guest speakers, sponsor field trips, help fund special projects, and hire teachers for summer or other work.

"We believe that young people need to be increasingly literate technologically, no matter what career path they take," said Margaret Pantridge, director of community relations for Needham-based PTC Corp., which provides free design software and training to schools and teachers across the state. "Public schools have a responsibility to make sure students will be able to function in the world in which they're going to be living, and people who don't understand technology in the broader sense are just going to be left behind. We're most passionate about middle schools, because there's still an opportunity to get to every child of every economic group before they get turned off by math and science."

Besides such direct in-school programs, other companies seek to improve overall educational quality and curriculum. EMC Corp., for example, has played a leading role with Business for Better Schools, which champions high standards in MCAS. Such efforts benefit society overall, and businesses have a clear self-interest in backing MST education efforts. But companies and business associations must now ratchet up their levels of involvement. General support for programs that assist students and teachers must focus specifically on the daunting challenge of improving math achievement.

The most obvious reason is the need to keep the engineering pipeline flowing with the engineers, scientists, and other technologically skilled employees of the future. While collaborations between local schools and businesses are win-win, they are far from easy. "The companies want the product [technologically skilled workers], but they say it's the schools' job to produce it," said Cyr. "The schools say they don't have the money or the resources. Corporations' short-term time frames don't match education's long-term needs."

Donald Haile, EiMC Board member and president and CIO of Fidelity Investment Systems (a participant in EiMC's teacher externship program), said that match is critical to effective industry-education partnerships. "Industry has a responsibility to help in the whole educational system, but it is a two-way street," he said. "The [EiMC] externship program doesn't cost us a lot of money, and the long-term payback is great. We had four teachers last summer, who brought different approaches and views to us, and they learned a lot about industry. I think they went back [to the classroom] with a degree of excitement about what they were doing."

Analog Devices' Ray Stata, co-chair of EiMC, said his company has had similarly positive experiences with its teacher externs. He also praised programs run by Northeastern University and others that bring retired engineers into classrooms. He called for more companies to play a greater role—financial and otherwise—in supporting such efforts.

"Right now, many of these programs are teetering on the edge of survivability, because it's been hard to line up financial support outside the few large companies," said Stata. Whether small or large, companies could better promote retired-engineer and other programs among their own employees. And they should be willing to underwrite the relatively modest cost of training such retirees for classroom work.

Report From the Front Lines: Motivating Students to Be Engineers and Educators

Several of our interviewees suggested stronger links between schools of engineering and education. Engineering students, they said, are a largely untapped pool for K–12 MST teachers.

We asked a lecture hall full of first-year students at UMass Lowell's Francis College of Engineering what interested them in engineering and whether a teacher had played a role. We also wanted to know whether they've considered a teaching career and why—or why not.

General findings:

- Teachers played a role second only to family members in interesting students in engineering, though most of these teachers were at the high school level.
- Introducing engineering at much earlier grade levels would make a difference.
- Many students said they would consider a teaching career, but only if salaries were higher. The poor image of teaching and a lack of respect for teachers was also a major deterrent.

"I was inspired by teachers who motivated me to become an engineer. I want to teach math or science, but I need a job that pays well first."

Sara McCarthy, 18.

To motivate greater interest in engineering, "introduce (engineering) in the earlier years of school. Make it known how important engineers are."

Jason Coy, 19

"My friends and I wouldn't have anything to do, so we'd just design things, whether it was a rocket-powered toy car and how we would make it drive straight, or an inter-cooler spray for my car. We were always coming up with things." What would motivate him to think about teaching? "I suppose [students might be motivated to consider teaching] if teachers really told us that they loved their jobs, but it always seemed like their jobs were a nuisance."

Josh Jones, 19

"You can distribute the costs of such programs in a way that minimizes the costs on any one company."

But with Massachusetts companies facing hard times, especially in the technology sector, convincing firms to invest in such programs remains difficult. "If you're laying off 10 engineers, it can be hard to take on 10 teachers as summer interns," said Vedula. "You know it's the right thing to do, but sometimes you need stronger advocates for long-term thinking in many of these companies."

According to Hodgman, it can be difficult to entice teachers into summer programs, even with the stipend, and some teachers might use the contacts they make through corporate summer programs to find new jobs and leave teaching altogether. "In fact, the most important role teachers can play for these companies is to be great math and science teachers."

EiMC Recommendations:

- Better coordination is needed to connect industry programs to one another and to MST teachers. Private-sector organizations can help fill this role.

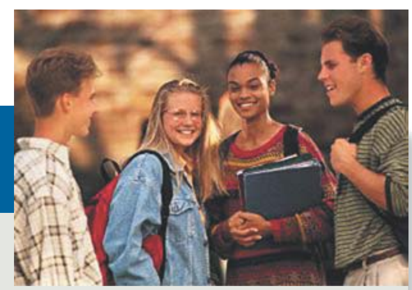
- There is a need to measure the long-term effectiveness of teacher-industry programs, both for industry and for the schools.

- Teacher/industry programs should run over several years in order to guarantee a steady income to teachers while offering continuity to companies and school systems.

A Final Word

There is no doubt about the importance of improved MST education and the central role teachers play. The challenge is to provide a training/teaching package that is accessible, flexible, and practical. "The problem is monumental, and it is all across the nation," said Eleanor Bonsaint, program administrator of MIT's Council on Primary and Secondary Education. The program brings MIT's many strengths to the American K–12 education system through projects that include the MIT/Wellesley Teacher Education/Certification Program, teacher sabbaticals, and educational outreach.

Over the past 14 years, the MIT Science and Engineering Program for Pre-College Teachers has assisted more than 1,000 teachers. Many of them remain involved with MIT's affiliate organization, the Network of Educators in Science and Technology, said Bonsaint. She knows that other programs are doing similarly important work. "But we're all little fiefdoms out here. There are many programs [involving MST education] right on this campus that I don't know about." Bonsaint hopes to address the problem by hiring a K–12 coordinator. "What we're doing matters, but given the scale of the problem, we're just making a little dent." It is time we had a major impact.❖



"I have considered teaching at the middle school or high school level, because I never knew what engineering was all about at that level. I wish I had been told what engineering involved and how deeply it impacts our lives. We had always learned science and math, but not how it all applied to engineering." But to teach, "there must be more room for financial gain."

John Roy, 24

"I would consider teaching because I enjoy math and science and some of my teachers taught me in a good way. It made me think about teaching like them." But … "the money issue."

Jackie Murawski, 18

"My motivation was from a high school teacher [who] made math interesting. I believe that the barrier [to motivating more students] was the teachers' lack of excitement. If they aren't excited, we as students won't be."

Bobby McGuinness, 18

"I could teach, but not high school or middle school. Kids have become more rude and disrespectful. More money could help. too."

Louis Ulsher, 19

"My eighth-grade math teacher told me I was very good at math and problem solving… (But) it would take a much better salary for me to even consider being a teacher. And I think it would be too hard to deal with kids all the time."

Nathan Brackett (no age given)

Report From the Front Lines: A View From the Teachers Desk

How did you personally become interested in MST? How important, if at all, were your own middle- or high-school teachers in motivating your MST interests?

"My dad was an engineer. We were always taking something apart or fixing something or building some neat gadget in the basement. My dad loved engineering and passed it on to me."

"I have loved math since I was young. I was a part of math team in high school and have always been good at math. I would say that my teachers encouraged me some, but not to a great extent."

"My interest comes mostly from a love of nature (thanks, Mom and Dad) and from the exciting varied experiences working with steel and concrete at the dams. I don't recall being inspired by anything in school other than theater set construction and acting."

Do you feel that the current MST curriculum and programs in your school are adequate to motivate students in general? Do you feel additional efforts are needed to motivate female or minority students?

"We have a reasonably self-motivated population: mostly upper-middle-class, mostly college-educated parents. It is generally assumed here that motivation is up to the students. I don't necessarily agree with this attitude, but given our population, it tends to work. Most of the MST teachers here are genuinely excited by their subject matter, and I do think that works to motivate kids. We as a group are not necessarily good at motivating or capturing the interest of the student who is beginning to question the value of school."

"If students are not already interested in science by the time they are in at least 5th grade, only the best, most interesting teachers and classes will get them interested. Our school system does not have anything that super-spectacular. I do not feel females or minority students need any special inspiration or motivation. By the time they are in middle school they are either interested or not. However, those students of any race or gender who are moderately interested can be turned off by a bad course."

"I try to make my particular science and engineering program for freshman as fun as possible, because I think that fun is the best motivator of all. As to females and minorities, I'm not sure that we need special programs just for them. I'm always a bit leery about singling out one group or another. I wouldn't argue with the idea that we need to do more in general to motivate students in MST."

"I do think we have to keep promoting the strength of girls in this area. I only have seven girls in my algebra class of 26 students this year!"

"To motivate students to be science, math, or engineering majors, they need early exposure. Many students are lost to these fields in elementary schools where the teachers are often science and math phobic, passing their phobias along inadvertently to their students."

"There is always more we can do to motivate ALL students in this area. The students do not see MST as areas of potential high income, nor do they see the importance yet of having a strong background for all fields of interest."

What is the best aspect of your job? The worst?

"The best aspect of my job is being with kids and watching them grow and learn. It is nice that for the most part, I have autonomy in my classroom. The worst aspect is having to deal with mandates from know-nothing legislators and administrators. Also, the pay could be better."

"The best part of my job is actually seeing students begin to understand a new concept or let go of a misconception. The worst part is trying to match what I teach to the MCAS or the frameworks."

"The best part of the job is working with students that are willing to try, make mistakes, and learn. The worst part is the mountain of paper work from the state and district."

"June, July, and August are great, time to think of new creative and exciting things to do, but once the school year begins we are in a 98-minute-long block, and there is little time for much except to move quickly. The worst part is 7:25 a.m.: time to be awake to perform, and keeping up with the paperwork and the demands of the state."

"I love the students. It is such a joy to watch a child learn and begin to appreciate math. The worst part of my job is the lack of time to prepare during the day."

Have you considered leaving the teaching field? If so, why? And what would make you willing to stay in the classroom?

"I have considered leaving whenever money gets tight around our household. It is interesting to me that although in theory, teachers are well-respected professionals, in practice, the respect level is not high. Teachers tend to be the bad guys in numerous ways whenever a student is doing poorly in class or whenever contract negotiation time comes around."

"I have thought often (more often since all this recertification garbage) of leaving teaching. Between all the work it takes to document courses for recertification, teaching to the MCAS, and trying to match the frameworks I am drowning in paperwork. If I were to stay and be happy about it the thing that would have to go is teaching to the frameworks. They are too broad. It is like teaching content an inch deep and a mile wide. The students never really have time to gain an understanding of most topics."

"Yes, [I have thought of leaving teaching because of] exhaustion from the schedule. Creative outside stimulation and time to be really effective would help me to stay. Also, it would help if the state would recognize that teachers do a good job at least half as often as they say that all teachers are morons."

"The lifestyle is appealing to me, I enjoy the school atmosphere, and yet I have considered new areas within education to explore. I assume it's only natural that with three degrees that I may be able to make a little more money."

"The income is insultingly low. I am tempted to drive a dump truck. College savings is a farce. However, the vacations are great. I enjoy summers tremendously, spent in part teaching technology engineering workshops."

Report From the Front Lines: A View From the Teachers Desk *continued*

If you were the state's education czar, what particular programs would you put in place to interest more middle-school students in MST? Please feel free to add any other comments about the general state of MST in the public schools—and what would improve it.

"I am a true believer in the engineering/problem-solving model of delivering science education. I find kids to be extremely motivated to do well in building their prototypes, and if the science concepts can be presented in a way relevant to improvement of prototype, kids will learn. So I would certainly encourage the development of more prototype-based curriculum."

"The biggest problem with science education is that elementary teachers do not understand science. I would certainly mandate some sort of "Science for Elementary Teachers" requirement for certification. Kids can get misconceptions from misinformed elementary teachers, but more important, kids in elementary grades do not develop science minds and do not begin to see the connections across science disciplines."

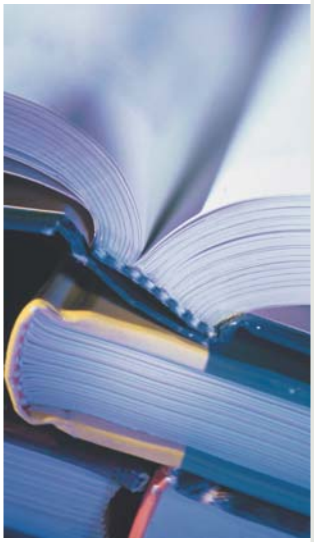
"Many kids in higher grades find science 'hard.'" I find that even in the ninth grade I am teaching what I consider to be elementary concepts that I believe they should know, like how to use the metric system and the basic laws of thermodynamics. Since at the high-school level there is an end point to be reached in content, defined by the College Board, sometimes the courses become too crammed, and if you're weak in basics, you don't have a good opportunity to catch up."

"All middle schools would have to have some form of tech or industrial arts class. Science at the elementary grades would need to be inquiry based and hands-on. By the time students get to middle school, after having hands-on science in elementary school, they would be ready for tech classes and science classes as well. Math basics have to be learned by all students even if they are not fun. It is embarrassing for many ninth graders not to know the times tables."

"Offer and make it easier to enter competitions like the Junior Solar Sprints. The easier part is financial support for the materials. And pay the teachers for their effort, like a football or basketball coach would be paid."

"Testing that focuses on creative problem solving and hands-on challenges, rather than testing that asks them to memorize this and that—questions that are easier to grade and therefore a cheaper option to test."

"I would love to see more programs like WISE (Women In Science and Engineering). All programs should be open to more students. A general program on careers in science and technology for both boys and girls would be great. Students respond to people who actually use these skills in 'real life.'"



Policy Brief: K–12 Mathematics Achievement

The Issue:

Despite consistent progress in reading and writing since 1998, students' math achievement remains stubbornly low both across the Commonwealth and nationally. This problem is serious because of the MCAS graduation requirement, the federal No Child Left Behind Act, math-deficient students' grim job prospects, and the dependence of our economy's technological, medical, and financial sectors on a highly skilled labor pool.

The Core Problem:

Many secondary math teachers and most elementary teachers lack the mathematical competence to handle new standards-based curricula and raise student achievement to acceptable levels. A chronic shortage of even poorly qualified math teachers is turning this already serious problem into a crisis.

The Key Levers:

The governor, state legislature, and Department of Education, in partnership with the business community, can resolve the crisis and make Massachusetts a national leader in math education by applying the following levers:

Training

Create a comprehensive, five-year, statewide initiative that will provide intensive mathematical content training to 10,000 teachers—3,000 secondary and 7,000 elementary—and to every college graduate seeking math or elementary certification. Pay stipends to those who demonstrate real progress in the training.

Offer competitive, performance-based grants to a regional consortia of colleges, universities, and school districts to design and deliver both rigorous, content-based professional development institutes and carefully targeted undergraduate math courses.

Put math specialists/coaches in the schools to continue and consolidate teachers' work from off-site institutes. Convene a panel of experts to design content and delivery standards for these programs.

Incorporate current math content institutes, the proposed Commonwealth HUB partnerships, and other ongoing programs under this umbrella. Rewrite state college and university budgets to ensure the participation and cooperation of their math and math-education faculty.

Certification

Require at least three content-rich, college-level math courses—designed to impart a deep understanding of elementary math—for elementary certification. Require a degree in a mathematical discipline (math, physics, engineering, etc.) for high-school math certification and a minor in a mathematical discipline for middle school. Modify the recertification process to require rigorous, content-based professional development.

Management flexibility and supplemental pay

Assure that superintendents and principals have the authority to require professional development for those who need it most. Help urban principals attract and retain people with high-demand math skills using stipends and salary supplements paid directly by the state.

Financing

Earmark $12 million in year 1, matched by $8 million from the districts' existing state-required professional-development spending (7 percent of $125/student). Ramp these expenditures up to $20 million and $24 million in years 3-5. The total is less than one percent of the state's $4.2 billion/year education budget.

EMC²
where information lives

For their efforts in bringing this report to fruition
we would like to acknowledge the dedication of:

EMC Corporation
The Business Roundtable
Engineering in Mass Collaborative
The Inform Marketing & Design Group
Northeastern University President's Office
Phil Primack
University of Massachusetts Office of the President

For additional information contact:

EMC Corporation
Christopher E. Goode
goode_chris@emc.com

The Business Roundtable
Susan Traiman
straiman@brt.org

Engineering in Mass Collaborative
Krishna Vedula
krishna_vedula@uml.edu

MassInsight
William Gunther
wgunther@massinsight.com

Northeastern University
Marian Stanley
m.stanley@neu.edu

UMass Office of the President
Karin McCarthy
kmccarthy@umassp.edu

This report can be found online at
www.emc.com/pdf/news/se_report.pdf
and at www.eimc.org.