World Class

The Massachusetts Agenda to Meet the International Challenge for Math- and Science-Educated Students

THE Great Schools CAMPAIGN

Mass Insight EDUCATION

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Mass Insight Education and Research Institute (project organizer)

Mass Insight Education is an independent non-profit organization focused on improving student achievement in Massachusetts public schools. Through extensive school district networks; training and technical assistance based on converting research into effective organizational reform practices; leadership development programs; public service outreach initiatives; and public opinion, policy and field research reports, Mass Insight Education supports the thoughtful implementation of the 1993 Massachusetts Education Reform Act, with a primary focus on its central initiative—the statewide effort to instill higher student achievement standards.

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The Massachusetts Agenda to Meet the International Challenge for Math- and Science-Educated Students

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Mass Insight EDUCATION

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“The jobs are going to go where the best educated workforce is with the most competitive infrastructure and environment for creativity and supportive government.”

— John Chambers, CEO, Cisco Systems
(as quoted in The World Is Flat,
Thomas Friedman,
Farrar Straus and Giroux, 2005)

“A day of reckoning is approaching for this region, and for our country, in engineering and science—unless we take steps now to change the course.”

—Bill Swanson, CEO, Raytheon Company
(at the 2005 Northeastern University
CEO Breakfast Forum)

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Preface

THIS REPORT draws on the findings of nearly four dozen others: national and international studies that speak with a strong, collective voice about what it takes to improve math and science education.

But our intent with *World Class* is not simply to synthesize those reports. It is to establish a statewide, working agenda for Massachusetts — a blueprint for how to enact the cumulative recommendations of the researchers and educators listed as references on pages 31-32.

The report is the first of a series following in the footsteps of *The Unfinished Agenda* (February, 2005), which proposed a focused, goals-oriented approach to the second decade of Massachusetts' landmark drive to improve student achievement and its public schools. Both reports are part of Mass Insight Education's non-profit Great Schools Campaign, co-chaired by Boston Foundation president Paul Grogan and Foley Hoag partner Gloria Larson. This report is also a K-12 public education companion to the report issued last year by Mass Insight Education's sister organization, Mass Insight Corporation. *Choosing To Lead: The Race for National R&D Leadership and New Economy Jobs* presented an action plan to help Massachusetts maintain its position as a sci-tech leader and to secure its economic future.

The group that produced *World Class,* the Higher Education Task Force on K-12 Math and Science (see membership at left), is one of a number of workgroups that grew out of the launch of the Great Schools Campaign and the publication of *The Unfinished Agenda* (available at www.massinsight.org). Co-chaired by University of Massachusetts President Jack Wilson and Nellie Mae Foundation President and CEO Blenda Wilson, the Task Force includes members of corporations, business associations, foundations, and institutions of higher education that recognize the importance of improved K-12 math and science education to the economic future of the Commonwealth. We acknowledge with a deep sense of appreciation their commitment to helping Massachusetts solve the challenge that lies before us. Their insights, and those of the school and district educators that helped to shape the recommendations in this report, can help lead to a better, more secure future for us all.

World class? The choice is ours. The best time to plant a tree, goes the old saying, is twenty years ago… and the next-best time is right now. Massachusetts, in fact, did plant some promising school reform trees a decade ago with the 1993 Education Reform Act. Those trees have begun to bear fruit — but need careful sustenance in order to thrive. Many of the recommendations proposed in this report carry little if any controversy; some carry little if any cost, while others will require investment. All, however, require that we *make a choice*.

The time to choose "world class" is now.

William H. Guenther
President

Andrew Calkins
Executive Director

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A Note About Mass Insight Education and the Recommendations in This Report

World Class: The Massachusetts Agenda to Meet the International Challenge for Math- and Science-Educated Students calls for, among other reforms, a range of school improvement services including professional development for teachers and the implementation of coaches in schools. These are areas in which Mass Insight Education is actively partnering with school districts across the state and in conjunction with a number of partners, including Lesley University, Learning Innovations at WestEd, the UMass Donahue Institute, and ASK Enterprises.

The scale of the challenge before us calls for capacity-building in every corner of reform: within the schools, within state and local government, and within the partner universities, nonprofits (like MIE) and for-profits that will play vital roles in the improvement of student achievement in math and science education. Great schools need strong partners, and MIE would be proud to have helped spur the development of many such partners in Massachusetts.

Executive Summary

No action today... and here are the news stories we'll see in 2015:

BOSTON — School districts across the state are reporting teacher shortages that are "worse than ever" in the areas of math, science, technology, and special education, according to a survey conducted this past week by the Department of Education and a consortium of non-profit organizations.

"It's no mystery," said a spokesman for the consortium. "These shortages have been building for years. People with math and science skills have attractive career options in other fields. What we need to do is re-examine the field of teaching and give it more of the aspects of other professions so it can compete — better training, mentoring, compensation linked to increasing levels of responsibility, better working conditions. Our schools are losing teachers to other professions, and to other states that have made strategic investments in math and science teaching."

SPRINGFIELD — A survey of area colleges indicates that the percentage of students in their freshman year who are being required to take remedial coursework has failed to decline for the fourth straight year. The percentage of students required to take math and science remediation courses, in fact, rose by 5 and 8 percent respectively.

"I'm not surprised. We are treading water, at best," said Springfield Public Schools superintendent Robert Williams. "That's especially true in math and science, where we've had trouble finding qualified teachers in the numbers we need them." Williams pointed to the absence of a coordinated statewide push to recruit and prepare math and science teachers as a continuing problem. "How can we improve student achievement," he asked, "when we have such trouble attracting teachers who know the material?"

BOSTON — Even as the national economy is picking up momentum and recovering from the 2012-13 recession, the Massachusetts economy is lagging, according to figures released today by the U.S. Commerce Department.

Unemployment in the Commonwealth is still hovering around 7 percent, well above the national rate of 5.5 percent.

One executive at a large high technology firm who asked not to be identified, said his company looked at opening a plant in the Bay State, but ultimately chose not to. "The permitting process is long, housing costs a mint, and there just weren't enough plusses to counteract those factors," he said. "Face it — Massachusetts is old and cold."

The Challenge

Massachusetts will see a slow decline in its ability to attract new jobs — following the current national trends — if we do not sustain a competitive work force in an increasingly technological world. The most important investments any state or country can make are in the development of talent. For a knowledge-based economy like Massachusetts', that means starting with math- and science-educated students graduating from the public schools.

- **The pipeline of students into science, technology, engineering, and math-related (STEM) college programs and careers is shrinking in the face of increasing demand**. Less than one of five Massachusetts SAT-takers expressed interest in STEM careers last year. The number of engineering degrees granted in the state *declined* by one-fifth through the 1990s. Massachusetts' high-tech, high-finance economy needs a highly capable workforce the way a car needs fuel. Without it, they both stop dead. [44, 38]
- **Student achievement in math by American students is shockingly low by international standards** — behind Singapore, Japan, and Finland, but also behind the Slovak Republic, Estonia, and Iceland — and is inadequate either to fill the STEM college pipeline or to provide the technical expertise required for most of today's jobs. Massachusetts' students fare well compared to other states, but in the global economy, skill levels of students in countries 5,000 miles away matter just as much as skill levels of students in Michigan. [46, 47]
- **Researchers agree that teaching quality is the principal factor affecting student achievement.** But teachers have increasingly been drawn from the bottom quartile of college students as new career options

have opened up over recent decades for minorities and women. The field of teaching has been slow to mature into a career with genuine professional attributes: high-caliber training, effective residency/mentoring experiences; highly collaborative, data-driven work environments; incentives for superior performance or particularly challenging job placement; and compensation linked to career ladders with increasing levels of responsibility. [13, 29, 39]

- **Weak mathematical content knowledge among teachers — particularly elementary school teachers, whose training has not kept pace with higher standards for math achievement — undercuts students' understanding of math and engagement in STEM activities in general.** [7, 8, 12, 35] National research indicates that students lose their interest in math and science by middle school. We have neglected the skills required for elementary and middle school teachers to provide students with the foundation — and the excitement — to succeed in high school math and science and continue their interest in college and career choices.

A Vision for 2015

Imagine a Massachusetts in 2015 that not only leads the nation in public school math and science education, but is among the *best in the world*. A place known for its sustained commitment to high-quality teaching, highly collaborative education/business/policymaker partnerships, exciting student engagement and minority recruitment programs in engineering and science, and superior achievement in STEM-related disciplines by students at all levels.

Due to its reputation for teacher training and the quality of public education, Massachusetts is the destination of choice for the nation's finest math and science teachers… High-qual-

World Class by 2015... and here are the news stories we'll see:

BOSTON — A total of 320 public school teachers from across Massachusetts were honored today at a Statehouse ceremony for achieving "master teacher" status in their school districts. Well more than half were teachers of math or science, continuing a trend that started with the state's math-science teacher development initiative in 2005.

Somerville's Keisha Jones, a middle school algebra teacher and curriculum leader, was one of those honored. "The credit," she said, "really belongs to the great training I received throughout my career so far — my pre-service program, the residency in Revere, the graduate training, and the collaborative professional environment in the two districts where I've worked. I have to thank the state. It was public money that funded the programs that kept me committed to teaching."

SPRINGFIELD — Nadia Jimenez, a senior at Springfield's Central High School and a city resident, has been awarded a full scholarship to attend the Massachusetts Institute of Technology in the fall as part of MIT's new Homegrown Excellence scholarship program.

Jimenez credited Central High's science teachers for her success. "When I started high school, I didn't think I could live up to the high standards they set, but they knew I could succeed and kept pushing me to live up to my potential."

The scholarship program, which began in 2010, awards ten full-tuition scholarships to graduates of urban Massachusetts high schools. "This is not about public relations," said MIT admissions director Claudia Simpson. "Massachusetts is producing some of the finest math and science students in the world and we want them here."

BOSTON — The U.S. Commerce Department today released a report showing that Massachusetts topped the nation in job creation during 2014. The Commonwealth added more than 50,000 jobs last year across a wide range of sectors, but job growth was particularly strong in the high technology area.

Analysts attributed the performance to a variety of factors, including the state's highly touted public school math and science programs, which have raised student performance to world-class levels and become a magnet for teachers.

When asked why her company opened an office in Worcester, Linda Johnson, CEO and founder of NanoFabrications, Inc, cited a talented labor pool. "High technology follows the talent," she said, "and Massachusetts is the place to go for the talent we need."

ity public school math and science programs have helped to generate a workforce that is truly world-class…. Increasingly, twenty-first century businesses prioritizing highly skilled employees choose to take advantage of this deep talent pool…. Massachusetts natives who could go anywhere thanks to the quality of their education choose to stay here because the state offers unparalleled opportunities for professional advancement. Students flock to our colleges and universities, attracted in part by strategic alliances between academia and the many companies that are part of a thriving high-tech economy. Even those who were trained elsewhere look for opportunities to come to Massachusetts because it's unquestionably *the place to be* for high technology. The days of slow economic growth and population loss seem a distant memory.

How does this vision become our reality?

Invest in Teachers

The right decisions today will lead Massachusetts to success in the future. The wrong ones — or not making choices at all — will leave our workforce and our economy underachieving. We know that nothing is more integral to improving student achievement than a high-quality teacher. We know that an unparalleled opportunity to refine our teaching workforce (more than one-third turning over in the next five years) is staring us in the face. We also know that the status quo — the current state of teacher preparation, insufficient pipeline of qualified new teachers, and lack of professional working conditions —will not produce the math/science public school faculty Massachusetts needs to bring our students to twenty-first century skill levels.

What are the choices we need to make?
(See box, next page.)

Invest in Students

High-capacity teachers are more than half the battle. But it is also important to build a math/science experience for students in Massachusetts that is highly engaging, staked to rigorous standards and curricula, and oriented towards challenging each and every student appropriately. This set of choices involves decision-making at the state policy level, in school and district offices and classrooms, in university and corporate boardrooms, in neighborhood community centers — and in the home.

What are the choices we need to make?
(See box, next page.)

Costs

The rosy scenario described on the previous page for 2015 won't come free. Investments must be carefully targeted to ensure the desired results. The cost for math and science content training alone would begin at $20 million per year, building on current effective programs funded with $4 million of No Child Left Behind federal money and ramp up to $50 million. With additional local investments in teacher coaches and state leadership academies for administrators, this is still a small investment for the opportunities it will provide in jobs and prosperity.

Recommendations

> **Three High-Leverage Steps to Take Today**
> - **Raise pre-service math and science course requirements for elementary school teacher candidates.**
> - **Require aspiring elementary school teachers to pass MTEL math and science tests, just as they have to pass a reading test today.**
> - **Provide intensive content training and coaching in math to current teachers in grades 3-8 at a scale that matches the need. Follow that math priority with an equivalent commitment to science training and coaching.**

1 Invest in Massachusetts' Teachers of Math and Science

1.1 Prepare New Teachers for Higher Math/Science Expectations

a. Require elementary-school teacher candidates to become proficient in math and science content, and pedagogy.

b. Create new teacher education pathways (math/science dual majors, middle and elementary math coach/specialists, larger roles for math/science departments in teacher preparation).

c. Use revised teacher licensure and certification standards to propel both of the above recommendations.

d. Institute a credible definition of "highly qualified teacher" under No Child Left Behind.

e. Increase the representation of minority and female teachers in K-12 education, in middle and secondary schools, particularly in math and science.

1.2 Build the Capacity of Current Teachers

a. Provide intensive content training in math and science linked to the adopted curriculum for all teachers.

b. Scale up successful math coach models in elementary and middle schools statewide.

c. Engage teachers who teach math and science with the state's STEM (Science, Technology, Engineering, Mathematics) business community through externships and other partnership programs.

1.3 Enhance the Status of the Teaching Profession

a. Provide comprehensive induction, mentoring, and support for new teachers during their first two years in the classroom.

b. Institutionalize career ladders and differential pay through supplementary compensation packages based on professional norms (market conditions, responsibility, performance, placement).

c. Support this maturation of the teaching profession through leadership development for school/district leaders and school committee members.

2 Invest in Massachusetts Students' Math/Science Experience

2.1 Challenge all students with rigorous curricula

a. Produce a model course of study in math and science, incorporating higher expectations and the availability of advanced math and science courses.

b. Provide for more academic time to bring students who are underperforming in math and science to expected achievement levels (in view of the state's implementation of a science MCAS/competency requirement for high school graduation modeled on the successful experience with MCAS remediation investments in ELA and math).

c. Provide special opportunities for top math and science students (advanced courses at universities or involvement by professors on high school campuses; regional math/science academies, magnet schools or charter schools; scholarships).

2.2 Engage students in active, inquiry-based STEM experiences (Science, Technology, Engineering, Math) to build interest in STEM-related careers

a. Invest in public/private partnerships to actively engage students at all levels in math, science, engineering, and technology (science fairs, robotics competitions, college/school/industry "challenges" of all kinds).

b. Enlist STEM companies to showcase related careers for students in their schools, putting a special emphasis on building interest among minority and female students.

c. Develop a coordinated state strategy for business and foundation partnership programs, building on the initial Board of Higher Education STEM pipeline programs but modeled on the more comprehensive efforts in other states.

d. Establish a center for ongoing evaluation and effective practice dissemination for partnership programs.

2.3 Expand parent and public understanding of the critical importance of STEM to the state's economic future

a. Produce and disseminate public service information about STEM, combining various independent efforts where possible.

b. Enlist policymakers, educators, and key business leaders in articulating the importance of STEM to Massachusetts and the intrinsic attractiveness and relative security of STEM-related careers.

FULL REPORT

World-Class:
The Massachusetts Agenda to Meet the International Challenge for Math- and Science-Educated Students

The Challenge

> *"Increased global competition, lackluster performance in mathematics and science education, and a lack of national focus on renewing [our] science and technology infrastructure have created a new economic and technological vulnerability as serious as any military or terrorist threat."*
>
> *—The Business–Higher Education Forum (2005)*

AMERICAN STUDENTS lag scandalously far behind their international peers. Massachusetts (and other states dependent on skills-based jobs) is headed for economic disaster if we do not enable our children to compete in an increasingly technological world. The demand for college graduates trained in science, technology, engineering and mathematics (STEM) is increasing, but the number of students interested in these disciplines is low: only 19% of Massachusetts SAT takers expressed interest in STEM careers last year. Student achievement in the Commonwealth today is low when compared to international standards, and our graduates' technical skills cannot fulfill the requirements of today's jobs. [44,38, 46, 47]

The U.S. placed **15th out of 45 countries** in the 2003 Trends in International Math & Science Study (TIMSS) and **24th out of 38 industrialized nations** in the 2003 Program for International Student Assessment (PISA).

U.S. students lag behind competitive countries in math achievement ...

Average mathematics scale scores of eighth-grade students, by country: 2003

Country	Score
Singapore	605
Republic of Korea	589
Hong Kong SAR	586
Chinese Taipei	585
Japan	570
Belgium-Flemish	537
Netherlands	536
Estonia	531
Hungary	529
Malaysia	508
Latvia	508
Russian Federation	508
Slovak Republic	508
Australia	505
United States	**504**

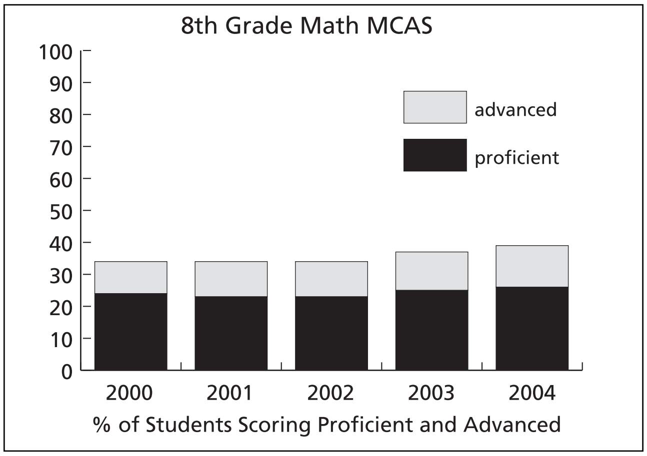
Source: International Association for the Evaluation of Educational Achievement (IEA), Trends in International Mathematics and Science Study (TIMSS), 2003.

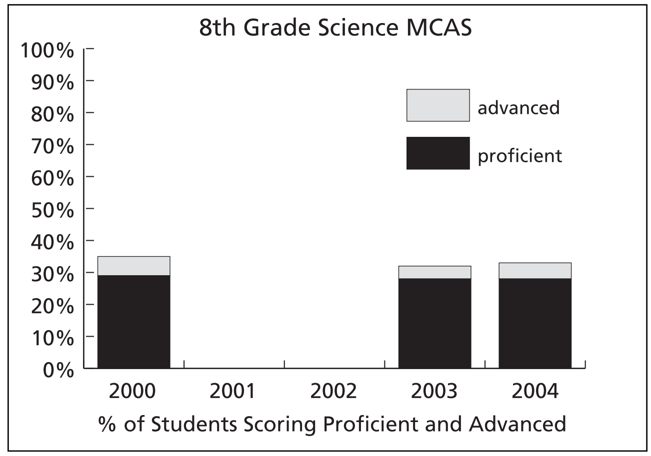
Combined mathematics literacy: 2003

Country	Score
OECD average	**500**
Finland	544
Korea	542
Netherlands	539
Japan	534
Canada	532
Belgium	529
Switzerland	527
Australia	524
New Zealand	523
Czech Republic	516
Iceland	515
Denmark	514
France	511
Sweden	509
Austria	506
Germany	503
Ireland	503
Slovak Republic	498
Norway	495
Luxembourg	493
Poland	490
Hungary	490
Spain	484
United States	**483**

Source: Program for International Student Assessment (PISA), 2003

... while eighth grade math and science achievement statewide stays flat





With no Sputnik II to spur real action, countless studies and reports sound the alarm but have been largely ignored for a quarter-century.

One of the most disquieting reports is *The Hart-Rudman Commission on National Security for the 21st Century*, released in February 2001, which warned the nation that a terrorist attack against the United States was likely to occur within the next 25 years. On 9-11, just seven months after the release of the report, this devastating forecast became reality. The Commission made specific recommendations to protect the security of our nation: 1) create a Department of Homeland Security; and 2) pass a National Security Science and Technology Act to foster science and math teaching at the K-12 level and increase funding for professional development in science and math.

The Commission's report stated that "the capacity of America's educational system to create a 21st century workforce second to none in the world is a national security issue of the first order." Ignoring the Commission's warning about science and math education may not have the immediacy of a 9-11 attack, but the erosion of our ability to have a technically proficient workforce could be even more devastating to our national and state economies. This report was certainly not the first to sound an alarm over the troubling trends in this country's science and math education. In 1983, the Nation at Risk report warned, "If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war." In 2000, the Glenn Commission on Math/Science Teaching expanded on those same sentiments: "[National and international statistics] echo a dismal message of lackluster performance, now three decades old; it's time the nation heeded it *before it's too late*."

The dean at one Massachusetts engineering school estimates that about half of the school's aspiring professionals lack the basic math skills required to complete their training successfully.

There are many reasons for the shrinking pipeline: many students are not being introduced to math and science by teachers that have enough content and pedagogical training to make these subjects compelling and exciting. Thus, many students lose interest in the subjects all together by the time they've reached high school, at which point it is almost too late to catch them up to levels necessary to succeed in college level math and science courses. And many students who pursue math and science have such low achievement levels (see charts on previous page) that they lack the skills necessary to succeed in graduate training or in the twenty-first century workplace. **The dean at one Massachusetts engineering school estimates that about half of the school's aspiring professionals lack the basic math skills required to complete their training successfully.**

A 2004 study by Achieve, Inc. found that employers and colleges are spending billions of dollars to provide their employees and students with the knowledge and skills they should receive in high school. Although three-quarters of students who do graduate high school go on to college, nearly a third are not college-ready and are placed immediately into remedial courses. [48]

If the United States were to rank 15th in the world in Olympic medals, it would be a national embarrassment bordering on scandal. Embarrassment and national pride would lead to investment and focus, which in turn would produce much better outcomes. Our students now rank 15th in the world in science and math. It is our moral duty and political responsibility, here in Massachusetts and across the country, to catch up to the rest of the world.

The Agenda for Change: How We Can Choose to Lead

The Task Force has organized its recommendations around two basic initiatives: investing in teachers, and investing in students — specifically, in all of the ways they experience math and science. The first implies a comprehensive restructuring of the ways we recruit, prepare, induct, certify, and support public school teachers in Massachusetts — using math and science as the proving ground for reform — and a long-overdue effort to professionalize a field that in too many ways lacks the primary attributes of a profession. The second involves a statewide commitment by government, schools, business, community-based organizations, and parents to creating the richest, most vibrant and engaging set of math/science experiences possible for every child growing up in the Commonwealth.

The reforms described here can have a broad impact on the quality of public education in Massachusetts — not exclusively on math and science. Urgency (borne out of an economic imperative and international comparisons) can produce focus and action, and a successful re-engineering of math and science education will serve as a model for all other disciplines as well.

BILL GATES, in a speech to the National Governor's Association at the group's recent summit on high schools, said in effect that we are getting close to "too late." "In 2001," he said, "India graduated almost a million more students from college than the United States did. China graduates twice as many students with bachelor's degrees as the U.S., and they have six times as many graduates majoring in engineering….In the international competition to have the biggest and best supply of knowledge workers, America is falling behind."

One global recommendation before we begin: The state must set specific goals for student and teacher performance in math and science teaching and learning, and has an opportunity to use the 2007 TIMSS test to benchmark Massachusetts against the United States and other nations. The state should commit today to the $500,000 it will cost to have this benchmarking conducted in 2007. (The state did participate in the 1999 benchmarking — before MCAS-driven reforms had much impact — and produced results showing Massachusetts lagging considerably behind other nations much as the entire U.S. did in 2003). We need data to demonstrate how far we have come and how far we have to go. The 2007 TIMSS benchmarking is the best, and in some ways the only, way to produce that comparison data.

Ready for the Real World?

Large percentages of college instructors and employers agree that public high schools are not successfully helping students develop critical skills. College instructors estimate that 42 percent of college students are not adequately prepared by their high schools to meet college expectations. Meanwhile, employers estimate that 39 percent of recent high school graduates are unprepared for entry-level jobs; they believe that an even larger proportion (45 percent) are not prepared to advance beyond those entry-level jobs.

2005 National Education Summit on High Schools. Sponsored by Achieve, Inc., and National Governors Association in partnership with Business Roundtable, the Education Commission of the States, and the Hunt Institute

Our students now rank 15th in the world in science and math. It is our moral duty and political responsibility, here in Massachusetts and across the country, to catch up to the rest of the world.

RECOMMENDATIONS: PART ONE

Invest in Massachusetts' Teachers of Math and Science

THIS INITIATIVE has two interrelated components — increasing the quantity and quality of STEM teachers, and completing teaching's transformation into a full-fledged profession.

The Issue: Stronger Preparation Needed for Teachers of Math and Science, Starting with Elementary Teachers

Researchers agree that teaching quality is the principal factor affecting student achievement. But a work environment that fails in too many ways to reflect professional norms prevents recruitment and retention of high-quality math/science teachers in sufficient numbers. Moreover, weak mathematics content knowledge among teachers prevents students' understanding of math, leading to low test scores and widespread aversion to mathematics. The state must set new standards for math and science teachers if Massachusetts expects its students to meet the new performance goals that have been set for them through the Education Reform Act of 1993 and the No Child Left Behind Act of 2001.

There is no shortage of teachers at the elementary level, but many lack the math and science skills needed to meet the higher achievement expectations that are now in place. Elementary school teachers in Massachusetts can earn a teaching license without taking more than one math course and without being tested (beyond minimal math questions on the state's multi-disciplinary MTEL elementary teacher exam). National research suggests that most children fall behind and have begun disliking mathematics by the time they reach middle school.

The dearth of mathematics content knowledge among elementary teachers was exposed in 1999 by Liping Ma's now-famous comparative study of American and Chinese math teaching [8]. Instructors in math content programs for teachers in Massachusetts, California, and Vermont report that a majority of K-6 teachers *do not possess a working knowledge of elementary-school arithmetic*.

Meanwhile, a chronic shortage of math and science teachers has large numbers teaching at the middle school level without subject area certification, and many are dual math/science teachers. Teaching math is difficult; teaching it in middle school is doubly so, and the strongest teachers often transfer to high school or take higher-paying jobs outside education. Moreover, both middle and high schools often use humanities or physical education teachers to teach a section of math or science because of high demand, thereby circumventing certification requirements. Pre-service college programs offer math courses but few emphasize the mathematics of the 5-8 classroom, deep content, or appropriate pedagogy to apply to 5-8 students.

Finally, most math teachers at the high school level are certified and shortages are less intense than in middle school, but those with the strongest math skills have higher-paying opportunities elsewhere. Teachers are frustrated because many students require exten-

> **In one typical pretest given to veteran fifth and sixth grade teachers, only 43% could correctly answer the question "75 is 30% of what number?" This is not surprising, since only 46% of math teachers and 57% of science teachers statewide had appropriate certification in 2000-01. High-school math and science teachers were 84% and 79% certified, respectively, in the same year [40]. The problem is far worse in urban areas; in Boston, for example — due mainly to the loophole whereby one can teach a single section of math or science out-of-field — only 15% of middle-school and 36% of high-school science teachers were science-certified in a 2004 survey. [42]**

sive remediation while high achievers too often lack challenging opportunities. Middle and elementary improvements will eventually "trickle up" and provide some relief, but reforms are still necessary.

Understanding Teachers' Knowledge

Effective teachers possess three different types of knowledge. *Content knowledge* includes knowledge of the content of the discipline as well as the processes that are used to generate that knowledge. *Pedagogical knowledge* (knowing how to teach) is necessary to communicate content knowledge in an effective way to promote student learning. *Pedagogical content knowledge* is a select domain of knowledge that is unique to the specific discipline and addresses the special pedagogical challenges each discipline poses for effective teaching.

For a more in-depth explanation of the three types of knowledge (Content, Pedagogical, and Pedagogical Content) that it is necessary to impart on new teachers in order for them to be truly effective in the classroom, see Appendix A. In addition, see Appendix B for a discussion of how improved teaching (and student achievement) depends upon a close alignment among curriculum, instruction and assessment. All three components of learning are necessary. Just as a weak curriculum can compromise strong instruction and assessment, strong curriculum and instruction can be compromised by weak assessment, and similarly, strong curriculum and assessment can be compromised by weak instruction.

Math and science should be symbiotic — good science utilizes and motivates mathematics, which in turn enables students to do substantive science — but a widespread lack of teachers' content knowledge that matches the skills students need in 2005 prevents this virtuous cycle from developing. Add to this the chronic shortage of math and science teachers, plus the imminent retirement of nearly one-third of the teaching force in the next five years, and we have a real crisis. It's time for the state government, institutions of higher education, and the business community to invest in teachers with the same unity of purpose that marked the first decade of education reform's investment in students.

1.1 Prepare New Teachers for Higher Math and Science Expectations

a. Require elementary school teacher candidates to become proficient in math and science content, and pedagogy.

The State must align the rigor of new-teacher training with the higher math/science achievement expectations for students' content. Currently, many pre-service elementary teachers leave high school lacking a mastery of even middle-school math and harboring a fear of algebra. In teacher-prep programs, they take one or two courses that are labeled college math but of necessity are largely remedial. In elementary classrooms, their unawareness of mathematical principles can beget ineffective, rote teaching (even with curricula designed to prevent it) and their math anxieties may infect their students, perpetuating the decades-long decline of American mathematics learning.

The place to break this cycle is in the colleges — with more substantial math and science courses, designed and taught by mathematicians and scientists for elementary teachers. For example, in math, these must impart deep knowledge and true mathematical perspective, focused on the arithmetic and geometry of the elementary classroom (examples of such courses exist in other states). Beyond that, pre-service teachers need a solid understanding of rates/ratios/proportions, number systems, number theory, algebra (which appears in the Frameworks as early as 1st grade), and trigonometry. Because of the high degree of remediation involved, most teachers will require three or four such courses. Pre-service programs for secondary teachers typically require more substantial courses and culminate in an MTEL math test.

Rigorous college math and science may be this report's most important recommendation in the long run, because it will break the vicious cycle, cost little (perhaps $1M) and, executed properly, create a new generation of math and science-knowledgeable K-8 teachers who will eventually make expensive remediation (see Section 1.2) unnecessary.

In addition, **pre-service college programs for teachers should have consistent, Commonwealth-mandated requirements that include specific numbers of months of student teaching in K-12 classrooms**. Schools should be identified as "teaching schools" where large numbers of pre-service teachers receive the care and feedback that they require during their student teaching (practicum) experience and are exposed to teaching diverse populations of learners. Financial resources should be available to these "teaching schools." Districts recruiting teachers from teacher education programs should have to report back to those programs and to the Commonwealth the regarding level of competence and success of the hired teachers. If teacher education programs do not produce successful teachers, a strategy report for change and improvement should be mandated for the program to maintain accreditation.

Opportunities to experience the actual "doing" of mathematics and science, alongside practicing mathematicians, scientists, and engineers, are also important to teachers at all levels. Programs such as PROMYS at Boston University are limited in scale, but modest increases in funding could provide considerable leverage and expansion. Internships and externships, now largely limited to fairly small programs sponsored by individual companies, are another avenue to rich experiences.

b. Create new teacher education pathways

As it stands now, the Education Reform Act of 1993 ended the practice of elementary teachers majoring only in education, but 43% in 1996-2000 opted for psychology or sociology — subject matter that is not taught in K-5 — often in a dual major with education. [41]. This practice avoids the academic disciplines that would better prepare teachers with content for the classroom; it also leaves little time in their schedules for the math and science courses that they so urgently need. Moreover, high achievers who are considering teaching want pre-service programs that are academically both challenging and relevant.

Courses currently required at two Massachusetts state colleges for completion of a degree in Elementary Education:

College A
- Passage of math skills tests
- One math class
- One science lab class
- Principles and Practices in Education
- Science in Education
- Teaching Mathematics
- Reading in Education
- Creative Arts in Elementary Education
- Social Studies in Education
- Reading in the Content Areas
- Language Arts in Education
- Foundations Seminar
- Practicum in Elementary I
- Practicum in Elementary II

College B

Math/Science Content Courses:
- College Mathematics I
- Introduction to Physical Science
- Biological Concepts

Education Courses:
- Education in American Society with Field Study I
- The Child and Literacy with Field Study II
- Elementary Curriculum: Mathematics with Field Study III
- Elementary Curriculum: Science, Social Studies, and Special Needs
- Elementary Professional Practicum A
- Elementary Professional Practicum B

Colleges and universities that prepare teachers should agree to change their requirements, to increase the content and pedagogical content knowledge demanded of their teacher candidates.

- **Math/Science Majors**: Mathematicians and scientists at two state colleges have proposed a refreshing response to this dilemma: math or math/science majors/minors designed for elementary teachers. This is an idea whose time is now-the state should move along this bandwagon with funding, reduction of non-content-focused pedagogy courses where appropriate, and an easier journey through the approval processes. At the same time, the state should encourage students (with scholarships or loan forgiveness) to sign up for these and other academically challenging majors. If the state really wants prospective elementary teachers to learn math, requiring them to take the full MTEL elementary math test (now required to become a math specialist) would do it, but would be a fairly controversial step.

- **Bachelor of Arts**: Another concept for a new form of pre-service training includes making a Bachelor of Arts degree in science available for students wishing to enter STEM teaching careers and STEM-related professions. Presently, many students expressing interest in the sciences or mathematics when arriving at college find after their freshman year that they do not wish to pursue a career in research. Colleges should continue to offer Bachelor of Science degrees for those students intending to go on to research work in graduate school, but we should not lose students who are interested in science and math because alternative degree programs are not available.

- **Specialists**: With 21,000 K-5 teachers in Massachusetts, it will take many years to overcome the content knowledge deficit in elementary schools. In the meantime, schools should maximize the impact of those few teachers with strong math skills by having them specialize in the subject by teaching two or more math classes (at least at the upper elementary grade levels). This can range from ad hoc swapping arrangements with another teacher to more formal departmentalization and specialization — a practice now explored in a number of Massachusetts school districts.

- **Alternative Licensure**: Special academies and intensive programs should be developed for people considering mid-career movement to STEM teaching. Financial support and incentives should be available for mid-career people with strong subject-matter skills to enter teaching. However, alternative licensure for mid-career people must require demonstration of competency of the same high standards in content knowledge, pedagogical knowledge and pedagogical content knowledge.

State Colleges on the Move

There are strong signals from some of Massachusetts' state colleges (which prepare most of the state's aspiring teachers) that they are committing to reforming their math/science teacher preparation programs. Currently, elementary teacher candidates at Worcester State College must take five mathematics and science courses including at least two courses from the math department and one science lab course. (In addition, candidates must take one methods course each in math and science.) Some faculty members are pressing for even more math, and for the creation of a new math/science combined major. At Bridgewater State College, president Dana Mohler-Faria (a member of the Higher Education Task Force that helped produce this report) has expressed his own strong commitment to revisiting the ways Bridgewater State prepares its teachers — particularly for math and science teaching — and to working with BSC faculty and staff to implement needed reforms.

c. Use revised teacher licensure and certification standards to propel both of the above recommendations

It is the responsibility of the Commonwealth to ensure all students have highly qualified teachers; this originates with teacher education programs and licensure requirements set by the state. Currently, the requirements for initial teacher licensure consist of: possession of a bachelor's degree; passing score on the Communication and Literacy Skills test; passing score on the subject matter knowledge test appropriate to the license sought (see box on page 15); completion of an approved program for the initial license sought; and evidence of sound moral character.

National reports and research [6, 10, 12, 13, 28] indicate that teacher effectiveness is

- Strongly correlated with subject matter knowledge, level of literacy, & selectivity of college attended
- Reliably measurable via value-added analysis of student achievement
- To a degree uncorrelated with education courses, master's degrees, certification, & years of experience

Consequently, it makes sense to focus license requirements on subject matter knowledge, focus education courses on those proven to be most useful in classroom practice, and send well-qualified candidates directly to on-the-job mentoring (as recommended by former IBM and Nabisco CEO Lou Gerstner's national teaching commission [13]).

UMass/Boston: Creating Bridges in Math and Science Education

The Center of Science and Mathematics in Context (COSMIC) was established in fall 2004 at the University of Massachusetts Boston. Directed by Arthur Eisenkraft, Distinguished Professor of Science Education, COSMIC serves as a bridge between the College of Science and Mathematics and the Graduate College of Education. COSMIC has several related goals. As the University looks toward fulfilling its responsibility to prepare students for a wide spectrum of careers in science, technology, engineering and mathematics, COSMIC sees, as one of its roles, ensuring that students receive the best educational experience possible. On another front, COSMIC provides support for science teachers beginning with their teacher training at UMass and continuing with professional development through their teaching career path as novice teachers, experienced teachers, and as teacher leaders. For the pre-college students, COSMIC develops innovative science curriculum materials and conducts research studies on their effectiveness. COSMIC also pursues projects that encourage pre-college students to consider science-related careers and to participate in courses and activities that can lead in this direction.

The Center is a promising model for the successful integration of various projects and initiatives under a single math/science umbrella. It is home to several major NSF grants: the new $12.5 million Boston Science Partnership, the $3 million Community Science Program, the $1.5 million GK-12 (Graduate Teaching Fellows in K-12 Education), the Active Physics Revision Curriculum Grant ($1.1M), and the Active Chemistry Curriculum Grant ($2.4M). COSMIC has also recently received a grant from the Department of Education for Preparing Teachers of Physics ($0.4M). Other present COSMIC initiatives include work on a National Academy of Sciences panel (The Future of High School Laboratories), a National Academy of Engineering panel (Assessing Technological Literacy), programs with Toyota, Toshiba, ESPN and participation in developing the framework for the next NAEP science assessments (The Nation's Report Card).

The Board of Education is already moving towards setting clearer standards for teachers of math and science (elementary generalists as well as middle and high school specialists). Rather than create a complex set of regulations, simplicity may be a virtue here. The Board should phase in a requirement for passage of the MTEL or another appropriate elementary math test of all those who will teach mathematics in an elementary classroom (including math coaches and coordinators).

MTEL exams in science and math are now required of all new science and math teachers in middle school and high school and all math and science specialists in elementary schools. MTEL exams in science and math should be required of all new teachers in elementary schools, just as aspiring elementary teachers currently must pass a reading test. Researchers including Deborah Ball at Michigan State are experimenting with new forms of testing for teachers that combine content with pedagogy — a promising development that should be explored when the models are ready (and have been tested themselves).

The objective is not to put barriers in front of prospective teachers, but rather to develop a system that prepares them to succeed. It is worth recalling a similar situation in 1998 when 58% failed the first MTEL exam, triggering widespread concern about the supply of new teachers and the academic worth of teacher preparation programs, which were required to reach a pass rate of 80% to retain their accreditations. In a classic, unintended consequence, colleges responded by making the basic MTEL an entrance exam before declaring a concentration in Education in the sophomore year. Nevertheless, the supply of new teachers was not throttled by the requirement that they demonstrate basic literacy, and it's now time to add basic numeracy to the list of teacher candidate expectancies. In the continuing absence of such a requirement,

What Massachusetts Requires of Elementary Teachers

In order to be licensed as an elementary teacher in Massachusetts, a candidate must pass the state's:

1. Communication and Literacy Skills Test
2. Foundations of Reading Test
3. Elementary General Curriculum Test of which 17% covers mathematics and 17% covers science

These are all part of the Massachusetts Teacher Educator Licensure Test for Elementary Teachers (MTEL). Using the figures supplied above, it's clear that a relatively minor portion of the state's overall assessment for new teachers is directly related to math and science.

The objective is not to put barriers in front of prospective teachers, but rather to develop a system that prepares them to succeed.

schools should move much more quickly towards specialization in the upper elementary grades as described above.

Offering bonuses or salary steps to high scorers who can also demonstrate — through evaluation — exceptional teaching skills would also send a powerful message that we are getting serious about lifting achievement in mathematics and science.

Relieving the severe shortage of math/science qualified teachers requires more than improving teacher-preparation programs. We must also create accessible, sensible pathways for high-achieving university and college students, plus mid-career individuals with experience in math, science, or engineering, to gain entry to teaching.

Alternative licensure is already a fairly quick process in Massachusetts: one can obtain an initial license with only a bachelor's degree, passage of the MTEL exam, and some practical classroom experience. The teacher then needs only a few years in the classroom and a master's degree before upgrading to a professional license. Unfortunately, potential applicants report that publicly available descriptions of the requirements and regulations are opaque and confusing. More can be done to encourage and expedite the transition of career-changing individuals with math, science, and other experience who wish to enter teaching. We should help them through the application process with a clear, concise web interface and then provide them (through extensive mentoring with experienced teachers) with a solid foundation of pedagogical skills.

d. Institute a credible definition of "highly qualified teacher" under No Child Left Behind

Federal law, of course, has something to say on these subjects. If Massachusetts is to fulfill the letter and spirit of the No Child Left Behind Act's provisions on teacher effectiveness, the state must develop a credible definition of "highly qualified teacher" and apply it to aspiring and current teachers alike.

According to a recent report by the National Council on Teacher Quality [9], Massachusetts' efforts on improving teacher quality received a grade of D+. An unqualified teacher can file a HOUSSE (High Objective Uniform State Standard of Evaluation) plan to take two courses and be designated highly qualified after completing one of them. Thus, one Massachusetts private college's course on "Mathematics for Social Justice," for example, would be sufficient to highly qualify a high-school math teacher under current rules. Elementary teachers need only include 10 hours of math instruction in their HOUSSE plans to become "highly qualified."

The definition "highly qualified teacher" set by the Commonwealth should be rigorous, comprehensive, consistent and measurable. To ensure that all those who need content training for example, actually receive focused, high-quality professional development, the state will need a combination of carrots (stipends, incentives for external assessments) and sticks (revisions of the PDP/recertification system, subject-matter tests). Current teachers need to be given ample time and all of the support they need to meet a rigorously defined "highly qualified" standard — but they should be held to that standard. Likewise, the highly-qualified requirement should apply to those who train and nurture teachers: math/science coordinators, coaches, and professional developers.

Our high MCAS standards for students draw national praise and our standards for educators should be just as high. Subject matter tests for teacher certification at all levels must be a part of this process if it is to be credible.

e. Increase the representation of minority teachers in K-12 education, and female teachers in grades 6-12, particularly in math and science.

Students in Massachusetts — and across the nation — see historical stereotypes about gender roles underlined on a daily basis through the teachers they have in school. They are unlikely to have a male elementary teacher; they are just as unlikely to see a female science teacher in high school; and they'll be lucky if they encounter even a couple of minority teachers in all of their twelve years in school. (Nationally, the percentage of teachers who are minority group members has declined to 10 percent in recent years, down from about 14 percent from a decade ago.)

None of this helps generate interest among girls in STEM careers, for example, or among Latino high school students in entering the teaching profession. A number of states have begun to take aggressive steps to build a pipeline of minority and female students into STEM careers; Massachusetts has invested $2.5 million in the Pipeline project coordinated by the Board of Higher Education. The BHE wisely created a regional structure for the initiative that encourages collaboration between institutions of higher education, school districts, and other partners. The structure is quite scalable, and deserves expansion — and an increased focus on recruiting individuals into science, engineering, and teaching who will refute ancient stereotypes by their presence in those fields.

1.2 Build the Capacity of Current Teachers

Teachers' weak content knowledge is at the heart of our national math and science problems, universally among elementary teachers but also to a disturbing degree — especially in urban areas — among middle school and secondary teachers. While a long-term solution is being implemented in colleges and universities (see above), we must also undertake short-term solutions with the current generation of teachers.

a. Provide intensive content training in math and science, to all teachers who need it.

Currently, small pilot programs already deliver serious content-focused professional development (PD) through the state's summer institutes, university and corporate sponsorships, and federally funded programs — a total of about $4M/year. The state has also focused its final year of funding from the federal Comprehensive School Reform program on integrated math reform initiatives with content training at their core. (Note: Mass Insight Education, together with partners including Lesley University, Learning Innovations at WestEd, and Classmeasures Inc., manage some professional development programs with funds received through these competitive grants.) Most of these programs focus on serving high-need districts (those serving high percentages of disadvantaged students; within those districts, the programs are largely serving upper elementary and middle school teachers who lack certification in math and/or who had not had much in the way of math training while undertaking their teacher preparation programs.

The DOE and Board of Higher Education deserve credit for collaborating on these initiatives and for focusing what resources they

Synopsis: Teacher Qualifications Today

Here is a snapshot of the math/science teacher capacity challenge facing Massachusetts. While the problems listed are generally greater in urban schools, they are certainly not limited to them. The expected retirement of nearly one-third of teachers in the next five years presents both a challenge and an opportunity to increase math/science expertise in every school district (according to the Massachusetts Teachers Retirement Board).

Elementary school (21,000 teachers): *The problem starts here.*
There is no shortage of teachers at this level, but most do not have the math or science content training in their background that would be sufficient for them to bring students (especially in upper elementary grades) to new higher expectations in those disciplines. New frameworks, curricula, and assessments increase mathematical and scientific demands on teachers. But teaching colleges have not been required to raise their own standards for teaching math and science to teacher aspirants commensurately.

Priorities:
- Rigorous pre-service math courses designed for teachers, emphasizing the math they will teach.
- MTEL math and science test or equivalent required for all teachers of mathematics, K-12.
- Rigorous content programs matched with coaching for in-service teachers.
- Math/science majors to attract/encourage higher achievers.
- Support for non-education majors and career changers with strong math/science expertise.

Middle school (3,000 teachers): *The problem becomes a crisis here.*
A chronic shortage of math and science teachers has large numbers teaching without certification. In particular, teaching math is difficult; teaching it in middle school is doubly so, and middle schools run the risk of losing their best teachers to more academically challenging high school positions or higher paying jobs in industry. Pre-service college programs offer substantial math courses but few emphasize sufficiently enough the mathematics of the K-8 classroom.

Priorities:
- Rigorous content programs matched with coaching for in-service teachers (optional if already well-qualified).
- Additional in-service content training appropriate to middle school.
- Undergraduate math and science courses designed for teachers, emphasizing what they will teach.
- Financial and career opportunity incentives to recruit and retain highly qualified people.
- Support for non-education majors and career changers with strong math/science expertise.

High school (3,000 teachers): *Teacher content knowledge improves, but too many students have been lost.*
Most math teachers are certified although weak content knowledge is (anecdotally) common, especially in urban schools. Math/science shortages are less intense than in middle school, but those with strong math skills have higher-paying opportunities elsewhere. Teachers are frustrated because many students require extensive remediation while high achievers have few challenging opportunities. Middle and elementary improvements will eventually "trickle up" and provide some relief, but reforms are still necessary.

Priorities:
- Opportunities for advanced math/science content, faculty collaboration and "immersion" experiences, connecting with real-world STEM applications and in-district engineering and technology specialists.
- Opportunities as content instructors for elementary and middle teachers.
- Undergraduate math courses designed for teachers, emphasizing the math they will teach.
- Financial incentives, career opportunities, and support for career changers.

have in this area. But these programs reach a tiny fraction of all of the teachers in Massachusetts who need this training.

The state should scale up these programs with targeted funding, matched by districts, to reach more of the state's current 21,000 elementary and 6,000 secondary math teachers. Although it will take a budget of $50M/year over several years to get the job done in math and science, much of it can be redirected from money already allocated to other forms of professional development.

Quality control will be critical. The state's capacity to provide intensive content training in science and math needs to be expanded to meet potential demand. Encouraging the growth of a diverse marketplace of providers — all of whom should meet rigorous state standards for the nature and quality of their professional development programs — would ensure that the state's commitment to increased teacher effectiveness could be successfully carried out.

b. Scale up successful math coach models in elementary and middle schools statewide

In-class math coaching is another important ingredient, both to follow up on content training and to transport new knowledge back to the classroom. Research from the National Staff Development Council (among other groups) confirms that the most effective staff development includes direct links with teachers' current work in the classroom. In mature coaching models, schools have been able to institute truly professional cultures and structures that promote collaborative teacher learning on a daily basis. Instructional improvement is an embedded part of the regular school day and the operating routines of teachers and support staff. (See box below.)

Effective coaching, unfortunately, is limited by the same shortage of math/science-trained people that plagues teaching, so growth will be slow. But it is an important way to share the currently limited wealth of math knowledge in the schools, and sustain and extend

Towards a Scalable, Effective Coaching Model

The Boston Public Schools and Boston Plan for Excellence are national pioneers in designing coaching models for public schools. The Collaborative Coaching and Learning model (developed by both organizations) is being implemented across the entire Boston school district and has generated much attention nationally. Mass Insight Education's effective-practice research program, the Building Blocks Initiative for Standards-Based Reform, has sent teams of educators and researchers into several Boston schools in part to learn about the CCL model.

Several "Vanguard" models named by the Building Blocks Initiative have instituted CCL particularly effectively: the Donald McKay School (K-8), Richard Murphy School (K-8), and Charlestown and Brighton high schools. Vanguard schools produce student achievement levels significantly higher than other schools statewide serving similar student populations. The McKay School does so in part by taking full advantage of the flexible use of Title I funds that come with school-wide Title I designation. The school uses some of this allocation to pay for specialists such as a librarian and paraprofessionals to cover the classes of teachers attending weekly team meetings, led by math and ELA coaches. Brighton High School, meanwhile, gets maximum mileage out of CCL's eight-week inquiry cycles, which gather teams of teachers to examine a particularly difficult curricular or instructional challenge.

the content training being done with in-service teachers.

Coaching is also an important tool in supporting pedagogy and pedagogical content knowledge. Coaches are valuable guides for implementing curriculum, using data, and assuring that subject matter is current and correct. Mass Insight Education is presently constructing a math coaching model that places the coach at the center of each school's implementation of integrated math reform — mapping curriculum, organizing the analysis of performance data, and leading the school's development of grade-level and horizontal math teams.

c. Engage teachers who teach math and science with the state's STEM (Science, Technology, Engineering, Mathematics) business community through externships and other partnership programs

In addition to financial incentives, it's important to give the best teachers room and encouragement to grow even better, increasing their self-esteem, prestige, and motivation to remain in the classroom. This can be accomplished with:

- Advanced courses at universities, with financial incentives for high performance;
- Challenging laboratory work that motivates students to pursue STEM careers, while challenging teachers to stretch their pedagogical muscles.
- Math and science "immersion" programs such as BU's PROMYS, where teachers experience the actual "doing" of mathematics alongside practicing mathematicians, and Research Experience for Teachers (RET) at Harvard, UMass, and MIT. Both are examples of successful NSF-funded pilot programs that should be scaled up with state funding. Other such programs are run by the Center of Science and Math in Context (COSMIC) at UMass Boston.
- Seminar series like those held by the MIT Whitehead Institute for high-school teachers and students, pairing teachers with Whitehead "partners" and providing a year-long program of scientific enrichment and learning.
- Corporate sponsorships for summer- or semester-long internships in companies, laboratories, and think-tanks doing cutting-edge work in math, science, and engineering.
- Workshops for teachers to learn how to introduce hands-on engineering design and technology implementation in the classroom, and better collaboration opportunities with district engineering and/or technology specialists.
- Adjunct faculty members in high-school departments from higher education and industry, helping with courses, labs, and enrichment activities.

The state should create a master catalog of all such programs, publicize them widely to current and prospective teachers, and subsidize participation with stable, ongoing funding.

1.3 Enhance the Status of the Teaching Profession

a. Provide comprehensive induction, mentoring, and support for new teaches during their first two years in the classroom

Teaching as a profession requires comprehensive licensing, induction, mentoring, and support that are consistent across the Commonwealth and of high quality. Teaching as a profession presently begins with pre-service training including a supervised practical experience, the latter of which is often deferred for math and science teachers because market demand allows them to be rushed into the classroom with preliminary licensure.

But the coherence of a true professional training continuum for teachers, unfortunately, ends (for far too many teachers) on the day they enter the classroom. Nor do new teachers find that their new job carries with it the trappings of other professions: effective residency/mentoring experiences, a highly collaborative, data-driven work environment, incentives for superior performance or particularly challenging job placement and compensation linked to career ladders with increasing levels of responsibility.

There has been no shortage of national attention paid to this issue. There is fairly strong consensus about what needs to be done in many respects; the problem, as happens so often in public policy, has more to do with resources and the complexity of implementation than it does with knowing what needs to be done. Following in the footsteps of other occupations-turned-professions (especially medicine), we recommend a "residency" requirement for at least two years, during the induction phase of a new teacher's career. This residency requirement would pair the new teacher with a trained and qualified mentor or would group a set of new teachers with mentors that rotate throughout the school year. This residency requirement, modeled after medical residencies for new doctors, would provide guidance, instruction and feedback during the first two years of teaching. In the same way that we recognize that a doctor's education has only begun upon graduation from medical school, we must create a system that nurtures and further educates teachers once they arrive in the schools.

State support for induction and mentoring programs is not a new idea; the DOE provided resources for mentoring programs fairly broadly in the late 1990s, before budget cutbacks curtailed these programs early in this decade. A 2003 DOE/CEP report [3] and anecdotal accounts indicate that induction, mentoring, and support, in the aftermath of this on-again, off-again state support, is uneven at best. This is an area where targeted, monitored application of resources on an ongoing basis could make a big difference. With its history of support for mentoring and with some small district-based programs (evolved in part from the Massachusetts Institute for New Teachers [MINT]) already running, the state should:

- Expand existing programs and invest in sufficient DOE resources to assure quality control;
- Encourage districts and higher education institutions and other partners to experiment with apprenticeship or medical-residency-style models;
- Scale up to reach all districts (as required by the 1993 Education Reform Act).

There are compelling reasons of quality and cost-effectiveness backing a sustained state commitment to coherent teacher mentoring and induction. Teacher attrition is a serious problem, with some urban districts losing half of their newly hired teachers within their first four years in the classroom. When schools routinely lose teachers two to five years after their arrival, they are undercutting their own capacity to improve schoolwide. Schools lose teachers who have now moved through their first two "learning years" in the classroom; teachers lose the chance to build strong collaborative relationships with colleagues; children are subjected to an endless parade of inexperienced rookies. Some attrition is not only necessary, but desirable — it's one signal of a school with rigorous standards for excellent teaching. But schools do best when they pro-actively recruit promising teachers, work with them closely during their apprenticeship years (and pre-service where possible), and then move them along a continuum of professional development that challenges them and provides opportunities for growth. That costs money — but saves money too, in the coin of higher retention rates and less time spent on a cycle of constant recruitment and induction.

The residency program we envision takes the usual mentoring model several steps further. It would not assign first-year teachers, for one thing, to a fulltime course load. That will be challenging to accomplish at a time when many districts are being forced by budget cutbacks to lay off teachers. But a fully mature residency model would take direct aim at the "sink or swim" approach that marks most new teachers' induction year. It would also have the following characteristics:

- Apprentice teachers would have access to qualified, trained mentors that have been selected because of their leadership skills and not because of their seniority.
- Apprentice teachers would receive regular feedback on their performance and recommendations for improving their practice.
- Apprentice teachers would have lightened teaching loads for their first year and if possible, second year of teaching.
- Apprentice teachers would have access to other forms of professional development, including content institutes in fields where they need deeper content knowledge.
- Apprentice teachers would participate in active learning communities composed of other apprentices and selected mentors.
- Additional compensation must accompany the additional time that induction teachers will be devoting to their careers during these years and to the mentors who are providing guidance.

b. Institutionalize career ladders and differential pay through supplementary compensation packages based on professional norms (market conditions, responsibility, performance, placement)

As professionals, teachers should be provided with adequate time for planning and building learning communities. They should have access to adequate science materials, resources and facilities. Teachers should learn and prac-

How Two Massachusetts High Schools Build a High-Quality Faculty

Through a partnership with Boston College (most prominently, though other colleges are involved), Brighton High School in Boston recruits and hosts a large number of skilled student teachers each year. Drawing from a pool of strong student-teacher applicants, the school invests time and effort in pre-selecting especially promising teacher aspirants who complete their student teaching practicum at Brighton. These student teachers are fully integrated into all aspects of professional development and work closely with Brighton staff and administrators. Brighton then draws from this pool of aspiring teachers with direct experience in Brighton classrooms to fill open teaching positions. The teacher candidates, having been exposed to Brighton's professional culture, usually choose to stay at the school.

Hudson High School, meanwhile, has built such a reputation for excellence with its inquiry-based learning methods, strong district curriculum support, culture of professionalism and commitment to faculty development that it attracts proactive, selective job-seeking educators without even advertising for them. Teachers actively want to work in Hudson (a 2001 Vanguard model in Mass Insight Education's Building Blocks Initiative) in order to benefit from the structures, supports, and culture built by superintendent Shelley Berman and high school leadership. See www.buildingblocks.org for more information on both of these Vanguard models.

tice coherent strategies for choosing curricula that best enhances science and math education. Administrators cognizant of what to expect and look for in classrooms where excellent science and math education is taking place should supervise these professionals.

Recruiting and retaining qualified math and science teachers has long been a losing battle. The cycle is just as vicious as math phobia in elementary school: a shortage of math-savvy people entering the private sector pushes salaries up, attracting math/science teachers away from schools; their absence leaves students even less proficient in math, increasing the original shortage and driving salaries higher still. The problem will only worsen as 30% of the teaching force retires over the next five years.

There is only one way to relieve this shortage: teachers' salaries must reflect market conditions and professional norms. In most labor markets, a shortage results in rising salaries; in teaching, as is painfully noted in Massachusetts Department of Education's "An Analysis and Evaluation of the 12-to-62 Plan for Recruiting and Retaining Teachers in Massachusetts," [3], the response to shortage is a reduction in quality.

What Makes a Profession?

From the point of view of math/science professionals with diverse job opportunities, a career in teaching looks underpaid and unappreciated. Troen & Boles [39] discuss what constitutes a profession and show how, in each category, teaching doesn't qualify:

* High-caliber training
* Effective residency/mentoring experiences
* Highly collaborative, data-driven work environments
* Incentives for superior performance or particularly challenging job placement
* Compensation linked to career ladders with increasing levels of responsibility

The state can tinker around the edges with stipends and bonuses, but real progress will come when collective bargaining agreements include flexible pay scales based on market conditions, performance, incentives, responsibility, and difficulty of assignment. Teachers receiving supplemental packages could be required to work more days devoted to professional development, training or mentoring other teachers, or doing additional work with students.

Financial incentives and alternative compensation packages should also encourage teachers to participate in professional development programs that meet state criteria for relevance and impact. Other financial incentives should be in place to encourage our best teachers to migrate to the poorest performing districts — or, within their own district, to the poorest performing schools.

Turning teaching into an authentic profession, with authentic compensation packages, will dramatically improve the working life of every competent teacher in the state. ***The goal is to raise the pay, prestige, self-esteem, and competence of teachers to the level of medicine, law, and engineering.*** This is in the teachers' best long-term interest; the legislature is in a position to help craft new collective bargaining rules for a truly professional teaching force with flexible pay scales, effective professional development, and management flexibility.

c. Support this maturation of the teaching profession through leadership development for school/district leaders and school committee members

The changes in the school leadership roles played by teachers will not be successfully introduced in schools on a broad scale unless and until current school and district leaders — especially principals, superintendents, and school committee members — are prepared to embrace these changes. That implies acceptance of a substantially altered school organizational chart from the traditionally flat school governance hierarchy.

The state is already working on these issues in a number of ways, including the Comprehensive School Reform grants described briefly above, and the SAELP initiative funded by the Wallace Foundation. Massachusetts at one time invested fairly significantly in leadership development through intensive leadership institutes. Its programming for leadership is now more collaborative (working side by side with the Massachusetts Association of School Superintendents, for example), but severely under-resourced.

The Wallace Foundation, Broad Foundation, Southern Regional Education Board (SREB), and other national professional organizations have produced a fairly vast array of research on effective school and district leadership. The complexity of the research and the importance of the issue make it deserving of a report on the scale of *World Class*, which is focused primarily on teacher effectiveness. Suffice to say, here, that teacher effectiveness depends a good deal on the ability of school leaders to organize and unleash teachers' full professional capacities. Thoughtful, well-supported development (both pre-service and in-service) for principals and other school and district leaders is a vital element in ensuring the successful transformation of the teaching profession.

Current Collective Bargaining Rules that Need Adjustment

1. Do not use the seniority principle alone to assign mentors to new teachers, who might benefit from working with a younger, more recently trained teacher (or one with solid leadership/mentoring skills).

2. Suspend "bidding and bumping" — a vestige of the seniority principle — when it clearly undermines a school's or district's ability to train and place specialist teachers (e.g., math coaches) or to turn around a clearly underperforming school.

3. Eliminate sanctions against professional development during periods of work-to-rule, which negates school improvement plans.

4. In authorizing course work for Master's or Master's plus thirty hours, assign top priority for placement in mathematics and science content courses to those who teach math or science courses.

5. Eliminate barriers to effective professional development, such as bans on assigning teachers homework.

Invest in Massachusetts Students' Math/Science Experience

SUBSTANTIALLY improving the quality of classroom teaching in math and science — matching it to the increasingly high expectations we have for student achievement in those disciplines — would be a giant first step towards enabling our students to succeed in the competitive global economy they'll join once they graduate. But it cannot be the only step.

The Commonwealth's "pipeline" of students — particularly minorities and women — into science, technology, engineering, and mathematics (STEM) is stagnant, even as the technological, medical, and financial sectors driving our state's economy become more dependent on a highly skilled labor pool. The percentage of SAT test-takers in Massachusetts planning to enter STEM fields has been essentially flat for six years [44]. Our most successful and innovative companies — Raytheon, to cite one prominent example — report great difficulty hiring qualified staff and rely increasingly on labor from other states and countries.

American Companies Go Global for Staff

Thomas Friedman of the New York Times recently interviewed Craig Barrett, the chief executive of Intel: "Intel can be a totally successful company," Barrett said, "without ever hiring another American. That is not its desire or intention, but the fact is that it can now hire the best brain talent 'wherever it resides.' Intel is making its new engineering investments today…in China, India, Russia, Poland and, to a lesser extent, Malaysia and Israel. While cutting-edge talent is still being grown in America…it's not enough for Intel's needs, and not enough is being done in U.S. public schools — not just to leave no child behind, but to make sure that the best students and teachers are nurtured and rewarded."

How do we generate more interest from Massachusetts' next generation in science, math, engineering, and technology? What else do teachers, schools, and parents need to fan the spark of scientific curiosity that children naturally bring to school? How can the state, by choosing to lead in math and science, pave the way for broader educational improvements?

The answers, we believe are part curricular, part engagement-building, and part public outreach. But they all boil down to the same thing: making Massachusetts everywhere a thriving hotbed of science and math and engineering and technology — from classrooms to family rooms, company cafeterias to college commons.

2.1 Challenge all students with rigorous curricula

The state should leave no child out of its vision for challenging, engaging math/science education. Not only do we have the prospect of constructing opportunities for top students — providing mathematically and scientifically talented students with advanced opportunities to develop their skills, cultivating their interest in STEM and encouraging them to pursue degrees in those fields (or teach in those subjects) — but we should double our money by using math and science as a "trojan horse" for whole school change in the state's lowest performing schools. That is essentially the model being tested by the state's Comprehensive School Reform program. To fulfill either goal — challenging advanced students to greater heights or modeling school improvement through a math/science focus — we'll need to begin with consensus about a model course of study.

a. Produce a model course of study in science and math, incorporating higher expectations and the availability of advanced math and science courses

The best science and math education models will not have an impact if students in most districts do not have access to those models. The state's graduation requirements are limited in their scope. They are still for one year of American history and four years of gym — though all districts have set their own, far more complete requirements. However, far too often elementary students only have science for one 45-minute period a week. This is simply not sufficient time to teach students the level of science education they need to even become interested in science, much less start to be prepared for more advance scientific pursuits in upper grade levels. School districts should set minimum requirements for science and math education at all levels off of a state-recommended course of study: 150 minutes per week in the elementary grades, everyday classes through three years of middle school, and at least three years in high school.

(The Department of Education, while it has left course requirements up to local districts throughout the past decade of school reform, is contemplating developing course-of-study recommendations for the eleventh and twelfth-grade years in high school through its application to the National Governors Association/Gates Foundation "Honor States" grant program. Perhaps this could be a jumping-off point for similar course-of-study recommendations in math and science and other curriculum areas at all grade levels.)

Adequate time, of course, is not the only variable here; what is done with time is as important or more so. Teacher quality, curriculum quality, and adequate commitment in the school schedule are each non-negotiably important — but not sufficient, by themselves. There is a fourth element, though — one that has shown its capacity to propel the other three. That element is assessment linked with accountability. This report supports the new DOE requirement that students pass a statewide end-of-course science assessment prior to receiving a high school competency determination. The requirement, to be instituted beginning with the class of 2010, is an important addition to the mathematics and English language arts requirements that have been in place since 2003. Like the earlier requirements, it will play a key role in producing progress in curricular expectations, staff development for teachers, and finding time for science in the school schedule.

The science graduation requirement should be the signal for a comprehensive program to improve math and science teaching and learning in the Commonwealth, and we support it — as long as the state backs it up with significant funding for teacher training and student enrichment.

In addition, the test must be the right kind of test — meaning, an assessment that reflects science's special attributes and does not simply follow paths set by the state's successful experience in administering tests in math and ELA. The Department of Education has recommended producing end-of-course tests, as opposed to one single, cross-sciences exam. That approach may solve some issues, but may give rise to others. (If Jessica fails the biology test in tenth grade, does she take biology all over again in eleventh grade? Or does she switch to physics and hope for a better result? Will a new generation of eleventh-grade science courses aimed solely at helping students like Jessica pass their MCAS requirement spring up all over the state? Can a straight paper-and-pencil test adequately measure students' science-lab skills and their understanding of scientific inquiry?)

The DOE has made good use of science educators to produce its revised science curriculum frameworks. It should make equally good use of practitioners to wade through the delicate waters of science assessment. Members of the Higher Education Task Force on K-12 Math and Science, which prepared this report, have indicated their interest in being part of that discussion. There is no question of the enormous potential impact of the MCAS science requirement on teaching and learning across all of the sciences. Inclusion of science in the state's competency determination will focus the schools', students', and parents' attention on science education — a very good thing in itself — and ought to spark additional state investment to support the recommendations in this report. However, the science requirement carries risk, as well, and the success of its implementation will depend on the state's readiness to match accountability for students with adequate support for schools.

A Model in San Diego

"High Tech High in San Diego…was conceived in 1998 by a group of San Diego business leaders who became alarmed by the city's shortage of talented high-tech workers. Thirty-five percent of High Tech High students are black or Hispanic. All of them study courses like computer animation and biotechnology in the school's state-of-the-art labs. High Tech High's scores on statewide academic tests are 15 percent higher than the rest of the district; their SAT scores are an average of 139 points higher."

—Bill Gates, in his 2005 speech to the National Governors Association

b. Provide for more time to bring students who are underperforming in math and science to expected achievement levels

In view of the state's implementation of a science MCAS, and a complementary competency requirement for high school graduation; the state should model the new science expectations on the successful experience with MCAS remediation investments in ELA and math. The state spent $50 million dollars per year for two years (and lesser amounts in other years) to ensure that students at risk of failing the math and/or ELA exams would receive the extra attention required to help them develop passing-level skills. As a new science requirement comes on line, the same principle must be applied here. Student accountability is justifiable only if it is backed with sufficient investment in support.

c. Provide special opportunities for top math and science students

Talented math and science students need additional opportunities to expand their knowledge, develop interest in STEM careers, and prepare for rigorous higher education programs. Commonwealth-wide programs, including science fairs, robotics competitions, academic year and summer research programs, should be funded for these students on a systemic basis — not left up to ad hoc, unstable, cobbled-together funding sources. Industry/education collaborations including summer employment and research programs will encourage students to consider pursuing future STEM careers while still in school.

In addition, we encourage the state to help develop at least one (if not several) regional math and science academies, magnet schools, and/or math/science-focused charter schools to serve Massachusetts' most promising STEM students. These high schools would be modeled after the best attributes of the North Carolina School of Science and Math, the Illinois Math and Science Academy, High Tech High in San Diego, and equivalent programs across the country.

We can start by scaling up one local example, the Massachusetts Academy of Math & Science in Worcester, and investing in the scale-up of other schools focusing on math and science, such as Boston's O'Bryant High School, and its partnership with the Massachusetts Institute of Technology.

In addition, some Commonwealth (out-of-district) or Horace Mann (in-district) charter schools can provide a promising model for successfully educating at-risk students with challenging curricula. The charter school movement provides a number of useful lessons to Massachusetts educators and policymakers in how to successfully focus advanced teaching and learning on math and science. Strategies such as longer school days, one-on-one tutoring embedded into daily learning, more persistent contact with families, Saturday programs, experiential learning, smaller class sizes, inquiry-based curricula, and professional learning cultures are all elements that Mass Insight Education and other research groups have discovered in the state's highest-performing charter models. (The potential of charter school models — particularly Horace Mann charters developed with the support, not opposition, of district superintendents — to help improve the state's most underperforming schools will be a primary focus of the second Great Schools Campaign report, to be published later in 2005.)

2.2 Engage students in active, inquiry-based STEM experiences to build interest in STEM-related careers, including teaching

a. Invest in public/private partnerships to actively engage students at all levels in math, science, engineering, and technology

The Board of Higher Education's Pipeline Fund — created by the 2003 Economic Stimulus legislation — already supports a variety of activities for math and science students through seven regional networks. In addition, other important math and science initiatives are being developed and implemented by Raytheon, Intel, the Mass Biotech Council, the

Massachusetts Academy of Math & Science at WPI

The Academy, a collaborative effort among the Commonwealth, Worcester Polytechnic Institute, and the high schools of Massachusetts, is an 11th and 12th grade public high school for 100 academically accelerated youths. It emphasizes math and science within a comprehensive, interactive program. The rigor of the junior year classes exceeds high school honors and AP, with more than 1200 hours of instruction. Seniors complete a year of college, taking the same classes as other students at WPI, a nationally ranked engineering school, thus making the Academy the only public school in Massachusetts whose students attend a university full-time as seniors in high school.

See http://www.massacademy.org.

Mass High Tech Council, and others. However, all of these efforts, while wonderful and important, are fragmented. The state must develop a coherent strategy for delivering these opportunities to students and bring it to scale statewide.

b. Enlist STEM companies to showcase related careers for students in their schools, putting a special emphasis on building interest among female and minority students.

Industry and education collaborations including summer employment and research programs will encourage students to consider pursuing future STEM careers while still in school. One example of an effective collaboration is the California-based, national MESA program (http://mesa.ucop.edu), in which industry and education partners recruit, encourage, and support disadvantaged students as they learn to excel in math and science. In addition, the Massachusetts Institute of Technology has been developing an intensive partnership with the John D. O'Bryant School of Mathematics and Science that could serve as a potential model (See box at right).

2.3 Expand parent and public understanding of the critical importance of STEM to the state's economic future

a. Produce and disseminate public service information about STEM, combining various independent efforts where possible; and

b. Enlist policymakers, educators, and key business leaders in articulating the

A Meaningful K-12/Higher Education Partnership: MIT and the John D. O'Bryant School of Mathematics and Science in Boston

Three examples from this multi-faceted school/university partnership:

The Edgerton Center & the Departments of Aeronautics and Astronautics at MIT have been working with the O'Bryant physics staff to offer students exciting, hands-on scientific experiences, involving the installation of a state-of-the-art solar energy system and weather station at the school to provide a long-term educational tool that incorporates applications of science and technology.

SEED Program

The O'Bryant is one of eight urban high schools whose students may participate in the Saturday Engineering Enrichment and Discovery (SEED) Academy, a free academic enrichment and career exploration program, whose primary mission is to motivate promising local youth to pursue technical careers by equipping them with foundational mathematics, science and communication skills. It helps to close the achievement gap by preparing urban students for rigorous college study in math and science.

MIT Sea Grant: Classroom Aquarium Project

Through experiments on fish in the classroom aquarium, students at O'Bryant will learn about ecosystems, marine organisms, and the effect of pollution on marine organisms. The students use a desktop flexible video camera to investigate plankton and cells and engage in scientific drawing to learn about marine biology.

importance of STEM to Massachusetts and the intrinsic attractiveness and relative security of STEM-related careers

All of these ideas add up to a sizable public commitment. Mass Insight's own quarterly polling surveys show continuing strong support for education at the top of state government's list of priorities (20% in the spring, 2005 survey, at least four points ahead of any other investment area). But the cohesive, statewide commitment we envision will require strong, sustained public and leadership support. Business leaders, government leaders, and school leaders will all need to be out in front of the public on a continual basis, advocating for a steady, strong investment in math and science education. Partners including media companies, communications firms, and organizations such as the Red Sox and Patriots should be invited to the table — and become part of the solution.

Math, science, engineering and technology are all around us. Yet to many young people in Massachusetts, they remain mysteries — and not even interesting mysteries, because of the ways too many students encounter math and science in their formative years of schooling. We can do better than this. And we must do better. Our children's prospects to understand the world around them and to make a living wage, and our state's prospects to maintain a vibrant economy, depend on it.

Mass Insight's quarterly polling surveys show continuing strong support for education at the top of state government's list of priorities

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Appendix A

Content Knowledge, Pedagogical Knowledge, and Pedagogical Content Knowledge

Effective teachers possess three different types of knowledge. Content knowledge includes knowledge of the content of the discipline as well as the processes that are used to generate that knowledge. In science, content knowledge includes facts, theories and laws and the experimental investigations that give credibility to this content information. Teachers must know the content of the field in which they are teaching. Many of our initiatives focus on upgrading and/or updating the content knowledge of science and math teachers. Schools of higher education must provide strong content backgrounds to all prospective math and science teachers, including those teachers of math and science in elementary schools who may not be school specialists. Professional development activities should include opportunities to improve content knowledge as well.

Content knowledge, though necessary, is not sufficient for a teacher of math and science. Pedagogical knowledge (knowing how to teach) is also necessary to communicate content knowledge in an effective way. If content knowledge were sufficient, all instruction at the college level would be exemplary since college professors have exceptional content knowledge. Since excellent instruction is not universal at the college level, we must admit that other teaching skills are also necessary. Effective teachers create learning environments that are physically, psychologically and emotionally safe for students. Effective teachers test for student understanding, anticipate problems, maintain discipline, encourage learning, motivate students, keep good records of student achievement, chart growth, use assessment to inform practice, anticipate problems and listen intently. Pedagogical knowledge grows over time through practice, reflection and further study. Schools of higher education must provide comprehensive instruction and practice in pedagogical knowledge to all prospective science and math teachers appropriate to the grade level of the students. Professional development activities should also include opportunities to improve pedagogical knowledge.

Content knowledge and pedagogical knowledge, however, are not enough to teach effectively. Pedagogical content knowledge is a select domain of knowledge that is unique to the specific discipline and addresses the special pedagogical challenges each discipline poses for effective teaching. An effective physics teacher is knowledgeable not only of physics content, but also incorporates into teaching the research on misconceptions that physics students bring to the classroom. If students' misconceptions are not addressed, the learning of physics concepts becomes much less efficient if it takes place at all. For example, students learn about the phases of the moon in elementary school, again in middle school and once again in high school. Yet students who received high scores on tests of knowledge on the phases of the moon at different points while studying this topic are unable to answer the same questions successfully upon graduation from college. Every student in the United States has at one time or another learned why it is colder in the winter than in the summer, yet the majority of adults, when asked this question, provide the incorrect explanation that the Earth is further from the Sun in winter. Teachers with pedagogical content knowledge know which content is difficult for students to learn or retain. They also know the best strategies to address misconceptions and improve learning. Schools of higher education must provide comprehensive instruction and practice in pedagogical content knowledge to all prospective science and math teachers appropriate to the age level of the students. Professional development activities, therefore, should also include opportunities to improve pedagogical content knowledge.

— Dr. Arthur Eisenkraft

Appendix B

Curriculum, Instruction, Assessment

Improved teaching (e.g. instruction) will not bring about the required changes without a close alignment of curriculum, instruction and assessment. Student experiences in the classroom are framed by the curricula chosen. The table below illustrates the difference between typical science and math curricula, and curricula that are informed by research on how students learn.

	Typical Curricula	Informed Curricula
Presentation	Lists of facts and algorithmic procedures which, when applied correctly, lead to the right answers.	Questions that drive the disciplines and engage students in exploring these questions and finding answers.
Assessments	Simple recall questions define the nature of the material that is important.	Students are asked to explain the meaning of what they have learned and provide evidence science or math has for that knowledge.
Activities	Students are drilled to name the parts of the microscope or to memorize the quadratic equation.	Students explore how changes in the lens of a microscope increase magnification or why quadratic equations have two roots.

All three components of learning are necessary. Just as a weak curriculum can compromise strong instruction and assessment, strong curriculum and instruction can be compromised by weak assessment, and similarly, strong curriculum and assessment can be compromised by weak instruction. A curriculum that stresses scientific inquiry including designing experiments, analyzing data, and drawing conclusions based on the data, is highly recommended in the national standards and state frameworks. If assessment given to students focuses on vocabulary and memorization and never explores their ability to design an experiment or analyze data,, we would say that the curriculum and assessment are poorly aligned. In this case, the assessment could not gauge what the student knows and undermines the goals of the curriculum. Similarly, poor alignment occurs when a curriculum, requiring students to design experiments and analyze data, is taught by a teacher who writes vocabulary words on the board and tells students the results of an experiment they do not perform. In this case, the instruction would undermine the curriculum, and the goals of the curriculum would not be fulfilled.

— Dr. Arthur Eisenkraft

The Mass Insight Education and Research Institute is a nonprofit organization, founded in 1997, that is focused on improving student achievement in public schools through the effective implementation of standards-based reform.

Our work supports and is informed by close partnerships with 25 school districts in Massachusetts (the Coalition for Higher Standards), representing more than 300,000 students. Our programs concentrate on school reform in Massachusetts, but have been held up as national models and increasingly will support effective implementation of higher standards in other states.

We are:

Researchers and communicators: A key source of information and field research on education reform in Massachusetts — for interested stakeholders at all levels, from parents to policymakers — and a national resource for information on the effective implementation of higher standards, through our Building Blocks Initiative for Standards-Based Reform.

Policy facilitators: A leading statewide convener and catalyst for thoughtful, informed state policymaking on education-related issues.

Leaders in standards-based services to schools: A provider of practical, research-based technical services, leadership training programs, and consulting services to schools and school districts — all focused on organizational strategies that help schools and districts transform themselves into higher-standards communities of learning. We have provided intensive leadership training to more than 1300 school and district leaders since 1998. Much of our current work focuses on integrated approaches to math reform, through the Math Achievement Partnership and other programs.

See www.massinsight.org and www.buildingblocks.org for details.

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