Science, Technology, Engineering, and Mathematics Education Program Implementation in Massachusetts

Center for Science Education
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INTRODUCTION

Since the passage of the Massachusetts Education Reform Act of 1993, the Commonwealth public schools have been on a steady course toward improvement. Curriculum frameworks, accountability measures, and graduation requirements for students have resulted in steady increases on state curriculum assessments.

Yet, most professionals involved in education in the state agree that there is more work to be done to reach the goals of proficiency described in the 1993 Act. Passing scores on the Massachusetts Comprehensive Assessment System graduation tests for competency require only that students reach the "needs improvement" category. This is of great concern in a state whose future economic health will be determined by the number of high school graduates who are equipped to move into jobs in science, technology, engineering, and mathematics (STEM) fields.

In addition, certain sub-groups of students in special education programs, from low-income homes, or from homes where English is not the native language, fail to meet proficiency standards at an acceptable rate. Even in districts where performance is high, students are losing interest in careers in science, technology, engineering and mathematics.[1] And there are continuing questions about whether the focus on a few subjects in conjunction with abbreviated school schedules has limited creative and problem-solving content.

Since the development of the MCAS examinations in 1998, students have tended to master the content necessary for the graduation test at an increasing rate as the deadline approaches for determining competency for graduation. For the class of 2008, 92% of students have already achieved the competency determination in English Language Arts and Mathematics. However, on the 2006-07 State Report Card, 29% of eighth grade students failed to meet the standards in mathematics, and 25% failed to meet the standard in science. When added to the percentage of students who are meeting minimal standards in the "needs improvement" category, the results are 60% of eighth grade students meeting minimal requirements or failing to meet the math standards and 68% meeting minimal requirements or failing to meet the science standards.[2]

Many public and private organizations across the state have responded to the need to improve teaching and learning in the STEM content areas with a remarkable set of programs and initiatives. This paper presents many of the important initiatives now underway, although the list is not exhaustive. From a review of these programs, a study of documents, and interviews with 20 important actors in STEM education, an overview of the current state of STEM education programs is presented. Important challenges to STEM implementation are also described.

The purpose of this paper is to provide information to Education Development Center, Inc. (EDC) of Newton, Massachusetts on the status of STEM education initiatives in the State. With its fellow education research and development organizations in Massachusetts, TERC and the Concord Consortium, EDC has provided expertise and fostered policy initiatives in school reform and science and math education at the national level. Each of these three R&D organizations has years of experience in working with schools across the country in the areas of professional development, school system change, curriculum development, and math and science education. Except for major

colleges and universities, these organizations receive the largest amount of funding and support from the National Science Foundation for non-profit organizations in Massachusetts.

This paper is an initial effort to map the organizations involved in STEM education in the State, to describe what those program managers state are the major challenges involved in implementation, and to list some of their suggestions to bring a strategic focus to STEM implementation. In the process, the paper describes an enhanced role for the involvement of the major education Research and Development organizations that have not played a major role in STEM program implementation in Massachusetts, despite their experience in policy development at the national level.

BACKGROUND

In 2003 the Massachusetts Legislature passed the Economic Stimulus Act[3] that recognized the importance of developing career skills and interest in STEM areas among teachers and students in the State's public schools and colleges. The Legislature responded to the fact that the State's future economic health depends upon the supply of workers ready to assume jobs in the large sectors of the State's economy devoted to science, health care, finance, and technology.

At the beginning of the decade, Massachusetts students were not mastering mathematics content at many grade levels as determined by the MCAS assessments.[4] Inability to master science content was also documented when science and engineering subtests were administered in 2003. In addition there were lingering concerns about teacher competency in STEM areas. In some science subtests of the Massachusetts Tests for Educator Licensure, 20% to 30% of test takers failed the test. [5]

Through grant programs administered by the Board of Education and the Board of Higher Education, and through various efforts of private, non-profit, and business organizations, a unique effort was begun to improve student and teacher performance in STEM areas and create interest in STEM careers. Unfortunately, this imperative to improve student performance in particular subject areas coincided with a State recession and large cuts in the Department of Education grant programs and in Chapter 70 local aid payments to cities and towns. From 2001 to 2005 funding in local aid and Department of Education grants fell by over $400 million.[6]

At the time of decreased funding, local schools were being required by the federal No Child Left Behind Act to "make adequate yearly progress" in language arts and mathematics. The changes necessary to move to a continuous improvement system from an intervention system required schools and districts to redesign their systems. That redesign effort depended upon additional resources, especially for professional development programs for teachers. Between 2003 and 2005, instead of having more funding to improve systems and STEM programs, budget reductions forced a decrease in professional development efforts state and local programs by $27.3 million.[7]

THE RESPONSE

Since 2003, a large number of organizations and actors have joined with local schools and colleges in a unique effort to improve STEM education programs across the State. From interviews with major actors in the area of STEM education in the state, the following list of organizations and initiatives was generated. This list is not the complete universe of all STEM programs, but a list of the programs that were mentioned most often by interviewees.

Stem Education Programs

Organization	Program	Target audience
Board of Higher Education	6 STEM Pipeline Projects: * Programs vary from science fairs and summer programs to teacher professional development. * Nursing initiative, teacher development institutes, licensing and teacher preparation improvements.	Teachers and students in late elementary, middle and high school. college students.
CITI: Common-wealth Information Technology Initiative	Promoting ICT training of P-12 teachers and higher education faculty to use technology to teach and to integrate into all curriculum areas (ITAC); curriculum development.	Middle school, high school, and college students and faculty.
Department of Education	Office for STEM Programs (OMSTE) * 11 Partnerships with higher education and K-12 schools. * Several other initiatives involving curriculum, licensing and teacher development.	Teachers and students, predominantly in grades 5-8.
Intel Corporation	A professional development program for 1500 elementary teachers in three districts that will provide coursework and support to teachers in their schools.	Elementary teachers.
Mass Insight Education	Research, technical assistance, and advocacy organization to promote improved student and teacher performance in critical STEM areas.	Policy makers. Teachers and students.
Massachusetts Bioteach: Mass Biotech Council	* Curriculum and education programs for high school students and teachers. * Development of a mobile labs program.	High school teachers and students.
Massachusetts High Technology Council	Policy and planning to improve professional development for teachers in STEM areas.	Policy makers and teachers.
Massachusetts Life Sciences Collaborative	The new collaborative group that will serve as an advisory committee for the Governor's Life Sciences Initiative. Documenting over 75 STEM programs in the Boston/Worcester areas and developing a PreK-12 plan for promoting career education in the sciences. Also concerned with teacher preparation.	Teachers and students.
Massachusetts Technology Collaborative	The State's renewable energy agency. Web site with teacher materials, reference guides, and conference lists. Grants to local organizations for education teacher and student programs.	Teachers and students.
MetroWest Employment Board: Lift^2 Program	Summer externships and graduate courses for up to 80 teachers in high technology and biotechnology firms.	Teachers.
Museum of Science	Teacher professional development programs and the development of the engineering and other curricula in several areas. Teacher resources center.	Teachers and students of all ages.
Northeastern University Center for STEM Education	A variety of programs for students and teachers ranging from summer camps for students to professional development programs for teachers.	Prospective teachers, school teachers and students.
Rennie Center for Education Research and Policy	Research and policy organization focusing on those policies that will improve educational leadership and result in improved student learning.	Policy makers.
STEM Planning Committee	Led by UMass, coordination of efforts to mount an annual networking and best practices event, promoting planning and systemic progress to meet state goals.	All stakeholders including legislators.

CHALLENGES IN STEM PROGRAM IMPLEMENTATION

Despite this list of important efforts, there are several challenges related to STEM education implementation in the Commonwealth. These challenges include the lack of coordination of initiatives by a lead agency at the state and local levels. the capacity of the Department of Education and local school districts to implement reform, teacher preparation in STEM content areas, and alignment between the preK-12 and higher education system.

Coordination

There are 17 regional programs sponsored by the Department of Education and the Board of Higher Education that currently provide STEM professional development and student programs across the state. In addition, there are a host of public and private efforts that are described above. There are proposals in the works to establish an additional five regional Advanced Placement Centers through a possible Mass Insight Education grant and indications that the Department of Education is considering funding four regional entities to assist schools that have been identified as not making progress under the No Child Left behind Act.

If many different organizations are working in the same region, then who is the lead agency responsible for providing technical assistance, establishing standards of practice, equity of resources, and evaluation of programs? The reduced Department of Education capacity and the increase in private and non-profit participation have created many programs, few standards for evaluation and effectiveness, and gaps and redundancies in programming.

Some participants have suggested that a state plan might begin to address this coordination problem. This would be a helpful step and one that the Goddard Council and the STEM Planning Committee and many volunteers will tackle this year. But because about 50% of funding for professional development is provided by local schools, 11% by state agencies and only 2% by private or non-profit organizations, the main challenge of coordination involves the state/local educational agency relationship.[8] While it is clear that all segments of the community must be involved in STEM program implementation, particularly the business community, a state agency (or agencies working together) must take the lead in the coordination efforts. In the end, the problem of the lack of resources and lead agency coordination may be the chief barriers to a more coordinated approach.

A recent report by the National Center on Education and the Economy[9] proposes that states take over a major portion of teacher recruitment, compensation and preparation programs to provide better management and coherence of the educational enterprise. The Report also proposes strong state regulation of school standards, curricula, and assessments, the dissolution of school districts as we know them, and the outsourcing of several of these functions to quasi-public entities that would comply with public rules. This central state leadership of school districts with outsourcing of the local function is the result of a perceived lack of progress in education reform over several decades. Whether new governance structures will occur in Massachusetts is a matter of conjecture, but it is useful to consider how complex and difficult the problem is, what resources are needed to effect change, and what governmental structures must be in place to foster improvement in the system.

Department of Education Capacity and State Funding

As described above, cuts in state spending on education occurred from 2000 to 2004 when declining state revenues forced reductions in Chapter 70 local aid and funding for the Department of Education. In the 1980s the Department had a staff of over 900, many of whom were experienced practitioners employed by regional offices to provide technical assistance to local districts. That

number has been reduced by half. Between 2001 and 2004 Chapter 70 local aid for education fell by over $269 million and funding for the Department of Education grant programs fell by $236 million after being adjusted for inflation.[10] From 1994 to 2004 the percent of the Department budget in relationship to the total Massachusetts education budget fell from .44% to .24%. Several comparison states with the same size student populations have over 100 more staff members than the Department.[11]

Although the Economic Stimulus Act was meant to provide some funding and a regional capacity to improve education in STEM areas, the grant amounts appropriated by the Legislature and managed by the Board of Higher Education (about $300,000 over three years per region) are small compared to the total expenditures for professional development in the state (about $185 million in 2005). The amount of federal and state dollars involved in the Department of Education Office for Math, Science, Technology, and Engineering partnerships, the Department teacher content institutes and the other Board of Higher Education teacher grant programs are in the range of $4 million. [12]

Schools undergoing budget pressures and trying to redesign their systems require the support of personnel who are experienced practitioners in schools. Formerly this expertise resided in the Department of Education. When one examines the enormous challenges for schools and districts trying to redesign their systems, it is not difficult to see how that effort is undermined by the lack of a strong Department of Education technical assistance operation. When asked what assistance they might need from the Department, superintendents listed curriculum support, professional development, use of data and assessments, and increased time on learning as areas of need.[13]

Of particular concern are the large number of professional development programs operated by various organizations and the lack of strong evaluation designs to determine their effectiveness. There are a number of studies[14] that have documented the best designs for professional development programs and these designs have served as a reference for other states in their evaluation of best practices and programs. The absence of a lead agency to provide coordination, technical assistance, and evaluation means that some schools and districts may purchase programs that vary in effectiveness, that are redundant to other efforts in the district, or that ignore system support and redesign issues.

The Governor and Legislature have recognized the need for more capacity in the Department and the 2008 budget reflects increases in several areas. However, most interviewees agreed that the Department is now viewed as a compliance organization only, and is not viewed as having the capacity to provide technical assistance to local districts at a time when that support is critical. [15]

In addition to Department capacity, there is also widespread opinion that the Chapter 70 formula does not reflect changes in the requirements that must be met by schools to move all students toward proficiency in language arts, mathematics, and science and there are also concerns about the provision of the creative arts. In recent years attempts have been made to increase local aid to make up for the cuts from 2001 to 2004, but 50% of school superintendents state that they are operating at a level below that which they had in 2001.[16] A 2006 survey by the Rennie Center for Education Research and Policy found that 43% of Superintendents identified budget problems as a significant problem.[17]

What has occurred in Massachusetts over the past decade is the weakening of a strong state lead agency capability, reductions in state appropriations for education at the local level, and some

outsourcing of teacher preparation and student learning functions among various partnerships, initiatives and other agencies. Privatization without strong central leadership, standards, and guidance, creates a hodgepodge of programs and outcomes.

School and District Capacity

Although we don't know everything about how to effect school reform, we know that there are certain systems that must be in schools to enhance student learning on a large scale. These elements are: 1) a curriculum that is aligned across grades and schools and connected to state assessments and post-secondary programs and jobs; 2) professional development that builds capacity and support within the school and that is focused on school and district needs; 3) the use of student data to direct instructional practice and accountability for student progress; 4) the use of school wide formative assessments to track student progress; 5) control of school schedules to maximize time on learning; 6) strong leadership at the school and district level; 7) adequate support structures for students who arrive at school with few resources or with learning problems; and 8) adequate laboratory and computer systems to teach STEM programs effectively.[18]

This new approach to school organization and design is different from previous systems in which curriculum guides presented loose frameworks for teacher practice, individual classroom practices varied, there were few conversations among teachers on instructional practice, and there were few student outcome measures.

In addition to the problems associated with fewer dollars to support professional development, interviewees mentioned that there are (1) few resources to expand school schedules and increase time on learning in STEM areas; (2) an inability to find and hire qualified math and science teachers; (3) questions about which curricula are most likely to result in student increases in learning; (4) lack of laboratory and computer equipment; (5) and inadequate support for students with learning needs.

Many interviewees expressed the feeling that school districts already have enough funding to redesign their systems and improve instruction, but that they are just not up to the task. But several researchers and authors[19] in the fields of business and education have noted the difficulties inherent in redesigning complex systems with few new resources, while delivering services to clients with many and varying needs.

Teacher Content Knowledge

Many of the STEM initiatives focus on teacher content knowledge in mathematics and science. Data from the STEM Pipeline Indicators Project[20] indicate that teachers taking the Massachusetts Tests for Educator Licensure from 1993 to 2005 failed the science and math tests at a rate of about 30% per year. A study by Mass Insight[21] states that in Massachusetts, approximately 28% of middle school teachers are not math certified and that most elementary teachers are not sufficiently prepared in mathematics.

Knowledge of content in mathematics is particularly crucial at the elementary and middle school levels, where some students, especially those from low income homes or with special learning needs, can begin to fall behind in mathematics, the gate-keeper for entrance to higher level science and math courses in high school. Lack of lessons of quality combined with low levels of student support at the elementary and middle school levels can serve to segregate certain students from possible interest and careers in STEM areas. In a recent study in *Science*, interest in science and STEM careers by late elementary and middle students was determined to be a more important factor than student

performance in determining which students pursued STEM post-secondary education and careers. [22] The Board of Higher Education, the Department of Education, the MetroWest Employment Board Lift[2] Program, and several of the other programs described here are focusing resources and expertise on the matter of creating student interest and knowledge in the elementary and middle school years.

Several interviewees noted that the ability to attract qualified math and science teachers is difficult at best, and doubly difficult for districts with low resources and the inability to pay competitive salaries. Added to this complicated picture is the fact that requirements that elementary teachers major in a subject appropriate to elementary education makes it more difficult for prospective teachers to squeeze in the content in STEM areas necessary for high level instructional mastery. Interviewees mentioned the fact that many STEM teachers who have received certification through alternative pathways often do not have the pedagogical skills to deal with middle or high school classrooms, student learning and attention problems, and the other instructional issues that arise in today's public school classrooms.

The Department of Education is working with the Board of Higher Education to develop better performance expectations for teachers in STEM areas. These expectations will inform new licensing and teacher preparation programs. But traditionally, most teacher preparation programs have been loosely affiliated with public schools, except in the area of student teaching, and some teacher preparation programs have not caught up with major changes in school curricula that require different skills.

The STEM Pipeline Projects and the Department of Education Partnerships are meant to promote a closer alignment among the institutions responsible for preparing teachers, by supporting joint professional development programs that will close the gap between teacher preparation, school curricula and instruction, and student needs. These programs are rich resources and exemplars of an ideal alignment among teacher pre-service programs, professional development programs, employers, and student needs and career interests in STEM areas. Changes in teacher preparation programs, licensing requirements, and in-service programs will lead to greater content knowledge by teachers and will result in better programs, student outcomes, and career interests in STEM areas.

Alignment of the PreK-12 System and the Higher Education System: Access to STEM Careers

Many of the STEM Pipeline programs address topics that are critical for access to higher education for low income students. A recent review of research and initiatives on college and post-secondary access by Price and Coles[23] describes what is known about access and lists a number of initiatives being undertaken by organizations and states to align high school graduation standards with college entrance requirements.

The report emphasizes that the skills and knowledge necessary for post-secondary study are the same skills necessary for obtaining post-high school jobs. Researchers know that preK-12 preparation is very different for low income students than for students from high resource families. Preschool preparation may be poor, teacher quality and curriculum may be weak, and students have fewer social and planning supports to gain access to post-secondary education. If students attend college, they have fewer choices among institutions. Students with poor instruction in STEM areas are less likely to pursue STEM careers, even if they attend various career institutes or summer programs in high school, since the development of such skills should begin in the elementary and middle school years.

The four main practices necessary for all students to be successful in gaining access to college and skilled jobs are: 1) a rigorous preK-12 curriculum; 2) a personalized learning environment; 3) social network support and adult relationships; and 4) alignment of curricula from pre-K to 16.[24]

Several states have begun to address college access by (1) aligning high school graduation requirements with the skills and knowledge necessary for success in college and post-secondary careers; (2) coordinating student data bases for tracking student experiences across the K-16 system; (3) improving systems for transfer from community colleges to four year institutions; (4) and forming P-16 councils to coordinate funding and curricula across the system. Although many organizations are involved in this effort, the various Departments of Education, working with Boards of Higher Education, play an instrumental role in coordination and technical assistance.

In Massachusetts, conversations are in process regarding the most effective governance for a coordinated education preK-16 system and both the Board of Higher Education and the Department of Education are working on better alignment. Work is well underway on an integrated student data base that will enable smooth transitions from school to work and post-secondary education.

THE ROLE OF MASSACHUSETTS-BASED RESEARCH AND DEVELOPMENT ORGANIZATIONS IN STATEWIDE STEM EDUCATION: AN UNTAPPED RESOURCE

Although Massachusetts-based research and development organizations have had decades of work with schools in STEM and redesign areas, they have played only a peripheral role in these areas in Massachusetts. With the Department of Education capacity limited and local educational agencies under time and budget constraints, these R&D organizations can play a larger role by providing expertise in several areas:

- Evaluation: Partnering with the Board of Higher Education and the Department of Education to develop a standard evaluation process for STEM programs.
- Leadership: Working with state and professional organizations to provide leadership training in STEM and other areas.
- Library of Best Practices: Identifying best practices and programs and providing technical expertise to local districts in implementation.
- Curriculum: Working with local school districts to identify, implement, and evaluate specific curricular programs in STEM areas.
- Assessment: Developing formative assessments in curricular areas that are aligned with the MCAS and higher education entrance requirements.
- Career: Working with schools and employers to provide a smooth transition between school and work.
- Policy and Planning: Becoming members of STEM boards and planning groups and being involved in the conversation on STEM implementation.

In undertaking these efforts, the R&D community should reflect on the complex issues generated by the public management questions addressed in the report and work with state level agencies to ensure that they foster coordination and capacity building efforts at the state level. Care should also be taken to address conflict of interest issues that may arise when personnel from the organizations are involved in policy planning efforts that might eventually lead to work in various areas.

SUMMARY OF MAJOR CHALLENGES IN STEM IMPLEMENTATION

There are several challenges in implementing STEM programs in Massachusetts. From interviews and a review of documents, the following main issues have been defined: (1) coordination among the various STEM initiatives; (2) state funding and the capacity of the Department of Education to operate as the lead agency and technical assistance provider; (3) local educational agency capacity to implement reform measures; (4) teacher preparation and content knowledge in STEM areas; and (5) alignment of the preK-12 and the higher education system. Because these issues are layered and integrated, it is difficult to devise a strategy for affecting them, particularly when the problems are viewed from many different perspectives.

However, each interviewee described some actions that, taken together with others, might be combined into a workable plan or strategy:

- Designate a lead agency and provide that agency with the capacity to evaluate programs, provide technical assistance on a regional basis, and coordinate efforts at the local level.
- Examine the local aid formula to determine if that formula addresses the real needs of schools undertaking reform and providing support to all students.
- Develop a focused strategy for intervention that targets the age and grades where interventions will most likely result in STEM career interest and choices.
- Identify and evaluate the best STEM teacher preparation, professional development programs, and curricula, and develop a library of best practice programs and technical assistance personnel to provide support to local educational agencies.
- Develop statewide guidelines for evaluation of all STEM programs.
- Ensure the equitable distribution of resources, equipment, and job placement opportunities across the Commonwealth, with attention to low resource districts.
- Align the preK-12 STEM curricula to formative assessments and higher education and job entrance requirements.
- Continue efforts to extend school schedules and provide enhanced programs for students, especially in low resource schools.
- Continue efforts to upgrade teacher preparation and licensure and professional development programs.
- Involve Massachusetts-based research and development organizations at the State level in policy planning and implementation of STEM programs in Massachusetts.

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APPENDIX A:
SURVEY OF STEM PROGRAMS

The STEM Pipeline Project

There are a number of organizations and actors in the area of science, engineering, technology, and mathematics (STEM) education in the state. In fact, the initiatives are so numerous that it is difficult to track them all. However, most have a common focus: (1) to enhance teacher content knowledge in the mathematics and science areas; (2) to enhance student learning and opportunity to master mathematics, technology, engineering, and science content; and (3) to attract students to career opportunities in the STEM areas.

In part these initiatives have been spurred on by the Economic Stimulus Trust Fund of 2003 and the Economic Stimulus Act of 2006 to promote improvements in the quality of educational offerings, increase student participation in programs, and improve teacher competence in the STEM content areas. The Acts established the STEM Pipeline Program at the Board of Higher Education and established the Goddard Council, a legislatively designated Council of business and education partners to foster STEM programs. This year the Board has funded six regional partnerships among employers, higher education institutions, and K-12 school systems to foster the project goals. The Pipeline regional programs are described below:

1. **Berkshire Regional Network**: Math application student programs, STEM fellows project, regional resource center, state science and career fairs.

2. **Cape and Islands Network**: Student leadership program, after and summer school programs for career interest.

3. **Central Regional Network**: Professional development for teachers in physical science for grades 3-8. Regional partnerships with schools, colleges, and industry to implement a number of programs to advance STEM.

4. **Northeast Network**: STEM fellows program with teams of middle school teachers from 15 districts who will provide leadership in their districts after the program.

5. **Pioneer Valley Regional Network**: Science summer camps, implementation of the Museum of Science developed Engineering Curriculum, teacher professional development, STEM mentoring program for teachers, and multimedia workshops.

6. **South Coast Network**: Graduate education in critical STEM areas for 20 teachers and MTEL test preparation assistance.

From 2004 to 2006, several Pipeline projects received $2.3 million in state grants. Current projects are receiving $1.7 million of a $4 million state appropriation, and the Board of Higher Education has been awarded $4 million for a continuation of these projects in the 2008 budget. The projects are designed to serve as catalysts for the creation of regional partnerships and not as the sole STEM initiatives in a region.

Most interviewees agree that some of the regional projects are more successful than others. Support by higher education institutions and employers is considered to be a key factor in program success.

Current grants are relatively small (about $100,000 per year for three years for each Network), and the projects rely on the active support of various partners for program development and implementation. But the value of having a regional presence and network, and of uniting K-12 education, higher education, and local employers sets the stage for continuing development and a closer alignment and student transition from the preK-12 system to higher education.

Evaluations of the projects during their initial years of operation varied in format and requirements. Each project had its own evaluation design. This varying design of projects and evaluations made it difficult to estimate Project impacts across the State.[25] In 2006 the UMass Donahue Institute developed a global benchmarking and indicators design that will track student outcomes on a number of indices to determine if all projects related to STEM education in the State are moving student learning in the right direction.[26] But evaluation of professional development programs across the State that are delivered by a number of entities continues to be a vexing issue in STEM implementation.

The Board has also developed or worked with the Department of Education on:

- The development of a Nursing Initiative that seeks to expand programs for prospective nurses by developing curricula, fostering the use of technology, and developing better articulation agreements with colleges.
- Administration under Title IIA of the No Child Left Behind Act of teacher development programs in STEM areas. In 2006-07 these programs included 67 initiatives that reached 526 teachers.
- Administration of a state funded scholarship program for teachers teaching out-of-field.
- The improvement of the mathematics requirements for elementary teachers in the curricula of teacher preparation programs across the State.
- A joint effort with the Department of Education to assist in developing comprehensive teacher preparation, licensing, and professional development guidelines for teachers in STEM areas.

Because of research that has documented the importance of creating student interest in STEM careers in late elementary and middle school, the next round of STEM projects is expected to focus on creating student interest in the elementary and middle school grades.

Massachusetts Department of Education
In addition to the STEM Pipeline Projects, the Massachusetts Department of Education Office for Mathematics, Science, and Technology Engineering (OMSTE) sponsors regional partnership programs funded by the No Child Left Behind Act, Title IIB for approximately $2 million. These partnerships in eleven regions of the state combine resources of public schools systems and area colleges and universities in an effort to improve teacher knowledge and practice in key STEM areas. The 2007 Projects are:

1. **Building a Better Science/Technology/Engineering Background**: Worcester Public Schools, Winchendon Public Schools, and Worcester Polytechnic Institute. A seven-day summer program that runs for three years and focuses on core physics and engineering content. The goal is to increase teacher content knowledge in physics and engineering. http://www.wpi.edu/Admin/K12/Educators/

2. **The Coalition for Higher Standards Math Partnership Program**: Haverhill, Holyoke, Fall River, Fairhaven Public Schools, University of Massachusetts, Lesley University, and Mass Insight. The Project seeks to improve teacher quality in mathematics through a three year program. Teachers in grades 4-8 receive nine courses in mathematics and graduate credit.

3. **Intensive Immersion Institutes** in Mathematics for Grade 4-8 teachers: Lowell Public Schools, EduTron and MIT, Fitchburg State College, and Bristol Community College. Intensive immersion courses centered on math concepts, computation, and problem solving that reach 120 teachers and 2000 students per year. The project features evaluations that monitor teacher progress.

4. **Middle School Math Teachers Program**: North Adams Public Schools, North Berkshire School Union, Pittsfield Public Schools, Mt. Greylock Regional School District, and Adams Cheshire School District with Massachusetts College of Liberal Arts. A complement to the Science Teachers Program will focus on Algebra, problem solving, patterns and relationships, Geometry, and data analysis.

5. **The North Shore Science Partnership**: Revere, Saugus, and Somerville Public Schools with Northeastern University. Provide courses for a Master's Degree in Science to a cohort of 20 to 30 teachers. A three-year program focusing on Middle School Teachers. http://www.northshore.neu.edu/

6. **Project Salem**: Lynn, Salem, Everett, Malden, Gloucester, Hamilton-Wenham, and Danvers Public Schools with Salem State College. Graduate program for middle school mathematics teachers in grades 5-8. Increases teacher content knowledge and use of technology. http://teacherweb.com/MA/SalemState/Project_Salem/hf0.stm

7. **PV STEMNET Pipeline Middle School Science Technology/Engineering and Mathematics Partnership**: Holyoke, Westfield, Springfield, Mohawk Trail Regional, Pioneer Valley, Amherst-Pelham Regional Public Schools, and University of Massachusetts, Springfield College, Western New England College, Springfield Technical Community College, Westfield State College, Holyoke Community College and WGBY Radio. A course of study that prepares in-service and pre-service grade 5-8 teachers to be highly qualified in mathematics by providing six courses. http://umassk12.net/pvnet/mathscience.htm

8. **School Based Intensive Immersion Intervention**: Fitchburg, Gardner, Leominster Public Schools, Fitchburg State College, MIT, Bristol Community College and EduTron. Two intensive immersion programs in the areas defined above.

9. **The Science Improvement Project:** Cape Cod Region. Improving physical and earth science education in Southeastern Massachusetts and Cape Cod. Brockton, Barnstable, Fall River, New Bedford, and Plymouth Public Schools with Cape Cod and North River Collaborative, Bridgewater State College, Bristol Community College, and Cape Cod Community College. The Project seeks to improve the content knowledge of science teachers, grades 4-8 through a series of graduate level education courses in chemistry, energy and earth science.

10. **Strengthening Teaching and Learning in Middle School Science in Northern Berkshire Schools:** North Adams Public Schools, North Berkshire School Union, Adams Memorial School, and Massachusetts College of Liberal Arts. Intensive course in science for middle school teachers that includes on-site mentoring of teachers. Content areas are physical science, biology, and environmental science. Evaluation will include student testing.

11. **Worcester Math Initiative**: Worcester and Milford Public Schools with Clark University, Mass Insight Education, and EMC Corporation. Institutes focused on three elementary schools in Worcester where mathematics MCAS scores are well below the state average. Offered are intensive content courses, workshops aligning course content to the curriculum, and coaching of teachers in their classrooms by trained math coaches.

In addition to the Partnerships, the Department has several other initiatives in the STEM areas:

- Professional development institutes for the summer of 2007 will feature 26 courses in STEM areas.
- A joint program with INTEL, The Massachusetts DOE/INTEL Mathematics Initiative, will train 140 teachers for 10 full days of mathematics content during the first year. This program has been funded by INTEL for $1.5 million, by the Department of Education for $500,000, and by local districts for $275,000. Each teacher will proceed through an 80 hour curriculum. Over 1500 teachers are expected to proceed through the program in 3 years.
- A Mathematics Teacher Content Knowledge Assessment Pilot Study, which will develop diagnostic assessments for teachers to gauge their content knowledge in mathematics.
- Thirteen STEM focused public schools, including pilots, charters, and academies that enroll 7,575 students.
- Participation with eight states in Achieve's initiative to develop an Algebra II assessment.
- Development of resource documents that define the characteristics of effective STEM instruction.
- An eight-district pilot program that implements Galileo Online in grades 5-8 and includes the administration of a set of classroom formative assessments.
- Participating with the National Institute for School Leadership to incorporate math and science units into the curriculum.
- Participating and supporting the Mathematics and Science Liaison Network that includes participation by 22 of the largest urban districts and increases communication among them on STEM areas.
- Participation in the development of opportunities in biotechnology and in the development of a mobile labs program.

Other STEM Initiatives

There are a number of public and private collaborative projects in the Commonwealth that have been designed to foster the STEM goals.

- **The Commonwealth Information Technology Initiative.**
  A statewide public/private partnership that invests strategically in higher education and K-12 education to prepare students for careers in information technology. The Higher Education Grant Program is administered by UMass Amherst and the K-12 Program by the Donahue Institute at UMass. In 2007 the CITI program gave $470,000 in grants and scholarships. CITI

sponsors conferences and meetings across the state to promote technology education. http://citi.mass.edu/

- **INTEL Corporation.**
  INTEL has worked with the Vermont Mathematics Institute, the Massachusetts Department of Education, and three districts to refine the VMI curriculum and fund a $2.3 million teacher professional development institute that will result in 1500 elementary and middle school teachers progressing through an 80 hour content course in mathematics. http://www.intel.com/

- **Lift Program: Leadership Initiative for Teaching and Technology.**
  The Lift [2] program, developed by the Metro West Employment Board and funded by the Department of Education and business partners, provides 20 teachers per year with summer externships in high technology and biotechnology firms. Teachers experience real world applications of classroom knowledge in STEM areas. The program also requires that participant teachers take 3 graduate courses in technology, curriculum development, and other aspects of STEM career planning for students. Next year the program will expand to reach 80 teachers per year. http://www.lift2.org/

- **Mass Insight Education.**
  Mass Insight is a policy planning organization and field service provider that is supported by major business and educational institutions in Boston. Mass Insight Education supports programs that are focused on STEM areas, that seek to improve curriculum and instruction for all students, and that support higher standards and raising the ceiling for student performance. Mass Insight Education is a finalist for a large ($13 million) grant from the Exxon Mobil Corporation to establish five regional Advanced Placement centers across the State. http://www.buildingblocks.org/

- **Massachusetts 2020.**
  Mass 2020 is a non-profit organization that fosters improved learning opportunities for children and families. The organization has partnered with the Department of Education to expand the school day by two hours in 10 schools that have a large number of children at risk. The Legislature has appropriated $6.5 million for this first round of grants and is supporting planning for expanded schedules in 29 additional districts. http://www.mass2020.org/

- **The Massachusetts Biotechnology Education Program.**
  The Massachusetts Biotechnology Council is an organization representing 500 biotechnology business associates. Mass Bioteach is the educational foundation of the organization. Mass Bioteach promotes jobs and internships, supports professional development for high school science teachers, assist schools in curriculum development, and awards equipment grants to schools. In the 2006-07 year, forty-five schools were awarded grants to promote biotechnology education and attract students to careers in biotechnology. The organization is supporting work to establish a Life Sciences Academy that will include a mobile lab. The aim is for the lab to visit the 45 high schools of teachers who have participated in grant awards. http://massbio.org/massbioed/community_labawards.php

- **Massachusetts High Technology Council.**
  The Mass High Tech Council represents the high technology business sector and has a special interest in preK-12 education because its President was Chair of the Board of Education. The

Council addresses issues of teacher licensure in STEM areas and teacher professional development by participating in policy and planning discussions with key decision makers in the State.[27] http://www.mhtc.org/

- **Massachusetts Life Sciences Collaborative.**
  The Life Sciences Collaborative is a group of science leaders meeting to forward the Governor's agenda in the life sciences. The purpose of the group is to promote collaboration and discussion among the various businesses and agencies involved, to develop a strategy that will promote this sector in the State, and to include in the conversations major actors in industry, government, and academia. A major concern is the workforce pipeline. The group is working on a plan to develop a long range strategy for preK-12 education. Career education in the sciences and teacher quality are two critical areas under discussion. In a Power Point presentation the group assembled a list of 75 education projects in the sciences sponsored by universities, hospitals, and museums for students, mostly in the Boston/Worcester area. http://www.masslsc.com/

- **Massachusetts Technology Collaborative.**
  This Collaborative is the State's development agency for renewable energy. The organization will also participate in the Governor's Life Sciences Collaborative. The Collaborative sponsors a web site for teachers that includes a database, reference guides, lessons, books, and conference lists. The Collaborative awards grants to local organizations to provide education programs to students and participates in teacher content institutes with the Department of Education. http://www.mtpc.org/

- **The Museum of Science.**
  The Museum of Science has been instrumental in developing curricula and assessments in science, technology, and engineering for the Commonwealth and has a full range of professional development programs for teachers and student programs in several subjects. Its Gateway Project has worked with 50 school districts on science curricula. http://www.mos.org/

- **Northeastern University Center for the Enhancement of Science and Mathematics Education** (now the **Center for STEM Education at Northeastern).**
  The Center will coordinate the many existing outreach programs operating at Northeastern in the STEM area. Current programs include the Boston Science Partnership, the Bernard Harris Summer Science Camp, GK 12 Plus Program, the North Shore Science Partnership, Research Experience for Teachers, Re-SEED, and the Young Scholars Program. The Center will seek to share resources and manage many of the outreach activities. http://www.stem.neu.edu/

- **The Rennie Center for Education Research and Policy.**
  The Rennie Center provides research in policy planning for education. The Center focuses on those issues that determine successful implementation of education policy at the state and district levels. Recent reports have focused on state level capacity to implement federal education law and the systems and governmental structures necessary at the state and local level to make education reform work. http://www.renniecenter.org/

- **The Science, Technology, Engineering, and Mathematics (STEM) Education Institute.**
  Its goal is to, "improve K16 education by *fostering interactions* among school and college faculty interested in outreach, teacher improvement, educational research, and curriculum development." This is accomplished by providing K12 internet services for teachers, including

teacher workshops and courses, teacher preparation seminars, and grants. The STEM Education Institute also offers certification programs to prepare new teachers in mathematics and science. http://www.umassk12.net/stem/

- **STEM Planning Committee.**
  STEM Summit Planning Committee led by the UMass uses the Summits to attract educators, both PK-12 and higher education, community and business leaders and state and local-level policy makers to attack the challenge that currently, and in the foreseeable future, Massachusetts is not graduating enough students to fill the open STEM workforce positions. The purpose of the STEM Summit is to explore and analyze the problem and its solutions, extend exemplary, extant practices, determine the roles of the various players and mobilize the Commonwealth's STEM community to: increase student interest in and preparation for careers in STEM; increase the number of highly qualified teachers in STEM; and provide them with timely professional development programs support.

  Through the leveraging capacity of the Summit, the Committee intends to engage in the development of a state STEM plan and the necessary funding vehicles to support it, especially science and technology infrastructure, in collaboration with the legislature, PK-12 and higher education, business and associations. http://www.massachusetts.edu/stem/indexiv.html

- **University of Massachusetts STEM Initiative.**
  The purpose of the Initiative is to ensure coordination of all of the various efforts underway to promote STEM education and to highlight the need for a coordinated plan and the funding of infrastructure to support science. Problems in the implementation of a coordinated system have been identified as the lack of alignment among various programs, the lack of uniform standards for professional development, gaps in regional capacity and quality of programs, deficiencies in laboratory equipment, gaps in curricula in various areas, and redundancy from region to region. Of particular concern is the fact that the percentage of students interested in pursuing careers in STEM areas has declined in the past seven years. On its website, the STEM Planning Initiative lists 27 college and university STEM programs, four industry based programs, five governmental programs, and seventeen collaborative programs across the state. Some of those have been referred to above. http://www.massachusetts.edu/umassstem/index.html

This report was written by Nancy Richardson, Barbara Brauner Berns, and Judith Opert Sandler.

[1] Rennie Center for Education Research and Policy. (2005). *Reaching capacity: Blueprint for the state role in improving low performing schools and districts.* Cambridge, MA: Rennie Center, P9. www.renniecenter.org. *also,* The University of Massachusetts. (2007). The *Massachusetts STEM initiative. STEM Summit IV: Accelerating forward: Preparing Massachusetts students for careers in science, technology, engineering, and mathematics.* Boston, MA: University of Massachusetts. www.massachusetts.edu/stem/index.

[2] Massachusetts Department of Education. (2007). *New DOE report shows class of 2008 outperforming previous classes on MCAS*. Malden, MA: Department of Education. www.doe.mass.edu/news/news.asp. Also, 2006-07. *Massachusetts state report card: State achievement in English Language Arts, Mathematics, and Science.* Malden, MA; Department of Education.

[3] Section 29. Section 1 of Chapter 29 of the Massachusetts General Laws as amended.

[4] Massachusetts Department of Education State Report Card 2006-2007. http://profiles.doe.mass.edu/statere/part2.asp. and UMass Donahue Institute. (2006) *Massachusetts statewide stem indicators project.* Boston, MA: UMass Donahue Institute.

[5] UMass Donahue Institute. (2006). *Massachusetts statewide stem indicators Project.* Boston, MA: UMass Donahue Institute, P.8.

[6] Massachusetts Budget and Policy Center. (2006). *Facts at a glance: Funding public school education in Massachusetts.* Boston, MA: Mass Budget and Policy Center.

[7] Massachusetts Department of Education. *Professional development spending FY 03-05.* Memorandum to Senator Theresa Murray and Representative Robert DeLeo from Commissioner Driscoll. July 5, 2006.

[8] Ibid.

[9] National Center on Education and the Economy. (2006). *Tough choices or tough times.* San Francisco, CA: John Wiley and Sons.

[10] Massachusetts Budget and Policy Center. (2006). *Facts at a glance: Funding public school education in Massachusetts.* Boston, MA: Mass Budget and Policy Center.

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[12] Massachusetts Department of Education. *Professional development spending FY 03-05.* 2006-07 data was not available to the researcher. Sources for funding information for BHE and Department of Education grant programs were staff interviews.

[13] Reville, P. Testimony before the U.S. Senate HELP Committee. www.renniecenter.org.

[14] See for example, American Evaluation Association. (1995). *Guiding principles for evaluators* in *New directions for program evaluation* (66). W. Shadish, D. Newman, M., Sheirer, & C. Wye, (eds.) San Francisco: Jossey Bass; Creighton, T. (2001). *The educator's guide to using data to improve decision making.* Thousand Oaks, CA: Corwin Press; Dufour, R. & Eaker, R. (1998). *Professional learning communities at work: Best practices for enhancing student achievement.* Bloomington, Ind: National Educational Service; Easton, L. (ed). (2004). *Powerful designs for professional learning.* Oxford, Ohio: National Staff Development Council; Killion, J. (2002). *Assessing impact: Evaluating staff development.* Oxford, Ohio: National Staff Development Council.

[15] Department of Education General Appropriations Act. Fiscal Year 2008 Resource Summary. See also, Massachusetts Budget and Policy Center. (2006). *Facts at a glance: Funding public school education in Massachusetts.* Boston, MA: Massachusetts Budget and Policy Center.

[16] Interview with professional association staff.

[17] Rennie Center for Education Research and Policy. (2005). *Reaching capacity.*

[18] See Easton, L. (2004). *Powerful designs for professional learning.* Oxford, Ohio: National Staff Development Council; Elmore, R. (2004). *School reform from the inside out; Policy, practice, and performance.* Cambridge, MA: Harvard Education Press; Fullan, M. (2001). *Leading in a culture of change.* San Francisco: Jossey Bass; Killeon, J (2005). *Assessing impact: Evaluating staff development.* Oxford, Ohio. National Staff Development Council; Moss-Kanter, R. *Reinventing education: The change toolkit*; Reeves, D. (2005) *The daily disciplines of leadership.* San Francisco: Jossey Bass. Tucker, M. & Codding J. *The principal challenge.* San Francisco, CA: Jossey Bass.

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[24] Price and Coles, p.2.

