The Next Steps to Improving STEM Education in Massachusetts

Sponsored by the
Massachusetts Academy of Sciences
April 2009

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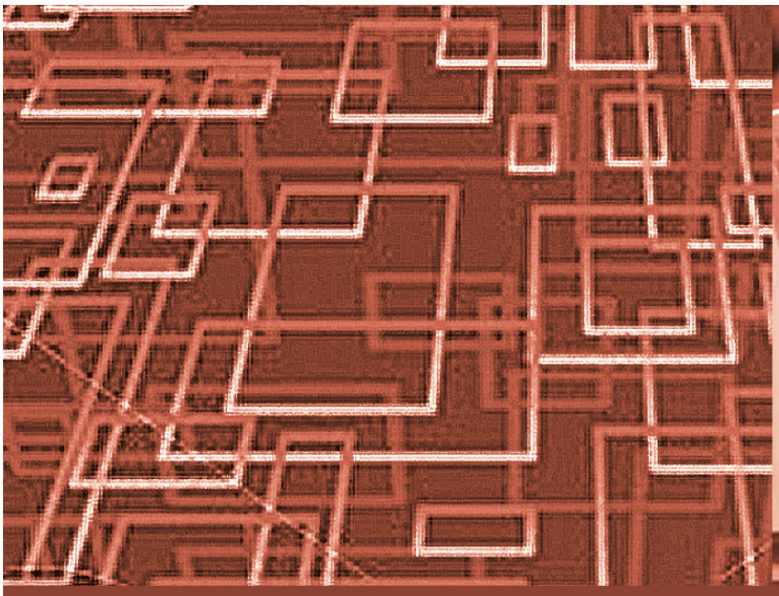

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The Next Steps to Improving STEM Education in Massachusetts

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EXECUTIVE SUMMARY

On 25 April 2009, the Massachusetts Academy of Sciences (MAS) sponsored a forum on science, technology, engineering, and mathematics (STEM) education to identify a set of priorities in STEM education reform in the Commonwealth. The forum had three objectives:

- *to have the greatest and most immediate impact on the students and teachers,*
- *to be suited to the MAS volunteer-based approach to STEM education reform, and*
- *once accomplished, to have a significant impact on the quality of STEM education in the Commonwealth of Massachusetts.*

The forum was stimulated by the "Readiness Project," launched in June 2007 by Massachusetts Governor Deval L. Patrick, and the resulting June 2008 report, *Ready for 21st Century Success: The New Promise of Public Education*[1]. MAS review of the report and underlying committee reports suggested that this strategic plan for education in the Commonwealth offered an opportunity to identify specific areas in STEM education that would benefit from volunteer-based reform.

While the Readiness Project covers the entire educational spectrum, the MAS elected to focus initially on the pre-K-to-12 arena. Accordingly, the following topics were chosen for discussion at the forum because they closely align both with the focus of the Readiness Project and with specific needs in STEM education at these levels:

- *Early Childhood Intervention and Assistance*
- *Raising the Achievement Levels of All Students*
- *Creating Conditions to Support Excellent Teaching*
- *Preparing Today's Students For Tomorrow's STEM Workforce and Its Leadership*
- *Informal STEM Education in the Commonwealth*

Following several plenary presentations to set the stage, working groups comprising K-12, college, and informal science teachers; students; school administrators; policy makers; industrial and academic scientists; and representatives of science education organizations tackled each of the topics and produced a set of recommendations intended to be useful to the Commonwealth and to guide the MAS in setting its priorities for addressing needed reforms in pre-K-to-12 education. The recommendations were discussed in plenary at the end of the forum. Not surprisingly, many of the specific recommendations of each working group, which are given in the body of this report, tended to overlap. Accordingly, the summary of recommendations here have consolidated and reorganized those that are closely related.

SUMMARY RECOMMENDATIONS

1. The State of Massachusetts needs and the MAS can facilitate the creation, maintenance and promotion of a web site devoted to STEM education and outreach resources in the Commonwealth. The resources should be routinely updated and annotated and a forum provided for users to discuss what works and what doesn't. The resources should include information to help to teachers, students and parents/ caregivers recognize science in their everyday life and understand the diversity of STEM career opportunities available.

2. In consultation with science teachers and educators, through working groups and conferences, the MAS should help to define the minimum amount of class time required to effectively teach science. Further, it should create a list of the recommended types of technology and equipment needed to translate this minimal time into the greatest impact on the student's engagement with and understanding of science.

3. The state of Massachusetts needs and the MAS can facilitate the creation and training of a volunteer core of STEM professionals to work with teachers, students, and parents/caregivers to find ways to bring science into their lives and to put a face on science, and science careers, in the Commonwealth.

4. The MAS can facilitate creation of a network of academic and industrial donors/ partners to help meet the laboratory and technology needs of public schools across the Commonwealth and provide training on how to use and operate the equipment and technology and incorporate these resources into curriculum requirements.

5. The state of Massachusetts needs and the MAS can facilitate the creation and promotion of a list of all STEM professional development resources available to teachers in the Commonwealth. MAS should provide annotation for each resource, giving the target audience, a brief synopsis of the program, contact information and links to the program material. The MAS can facilitate the sharing of professional development resources across districts and pooling of resources to provide more professional development opportunities. In addition, the MAS should initiate a "stamp of approval", based upon teachers' reviews and feedback. The MAS should advocate for the importance of professional development for STEM teachers and should provide letters of support for teachers to help them obtain release further education.

6. The state of Massachusetts needs and the MAS can facilitate a series of awards to support and promote excellence in science education and outreach. The awards should honor the efforts of school administrators, teachers, parents caregivers, industry and local government officials who create and implement solutions to the complex challenges of STEM education reform. Winners of the award should be honored at the MAS Annual Meeting and would be expected to promote science education and professional development.

INTRODUCTION

Governor Deval Patrick created the Readiness Project by executive order in 2007 as a ten-year strategic plan for the future of education in Massachusetts. This statewide initiative considered fundamental and systemic challenges that face public education in Massachusetts. The resulting report, *Ready for 21st Century Success: The New Promise of Public Education*[1], is a remarkably comprehensive document that spans the entire educational spectrum and lays out a broad roadmap for improving public education in Massachusetts. This proposal to reform public education comes at precisely the same moment that President Barack Obama, the National Governor's Association, the National Academy of Sciences and numerous professional education associations have challenged the nation to make Math and Science the cornerstones of education reform in order to ensure our Nation's global competitiveness.

The Massachusetts Academy of Sciences is committed to working with the Governor to achieve the level and quality of education reform articulated in his Readiness Project report, particularly with regard to STEM education. To help inform its agenda in this sphere of activity, the MAS organized an invitational forum on STEM education reform, to which representatives of the constituencies most affected by reform efforts would have voice and be encouraged to participate broadly in such reform. The forum's objectives were to identify a set of priorities in STEM education reform that will have the greatest and most immediate impact on students and teachers, that are suited to the MAS volunteer-based approach to STEM education reform, and that, once accomplished, will have a significant impact on the quality of STEM education in the Commonwealth.

The organization of the forum was coordinated by a steering committee that included representatives of several of the stake-holders in this initiative. It was tasked with creating a participant list, with care taken to ensure that a diversity of experience, background, views and interests relevant to STEM education, and ethnicity and gender were represented. The attendees included teachers and administrators from public and private schools, undergraduate and graduate students, professors and administrators from public and private universities, representatives from not-for-profit STEM formal and informal education and outreach organizations, and industry.

The steering committee also identified five areas of concentration for the forum. The following topics were chosen to align with both the focus of the Readiness Project and specific needs for pre-K-to-12 STEM education:

- Early Childhood Intervention and Assistance,
- Raising the Achievement Levels of All Students,
- Creating Conditions to Support Excellent Teaching,
- Preparing Today's Students For Tomorrow's STEM Workforce and Its Leadership,
- Informal STEM Education in the Commonwealth.

For each topic, the steering committee provided a set of sample questions to initiate and encourage broad ranging discussion. Participants were assigned to one of five working groups, each assigned to one of the topic areas, based upon their expertise and experience. The goal was to ensure that each working group included a subset of participants representing a diversity of experience and perspectives.

The Summit was convened on April 25, 2009. The morning session consisted of a series of brief informational presentations to provide a context for subsequent discussion. Dr. Jonathan King, professor of biology from the Massachusetts Institute of Technology, described the history of public education in the United States and Massachusetts, with an emphasis on STEM education, from the Civil War through the present day. He pointed out that universal education is a relatively recent phenomenon in American history, and was not brought to completion until the civil rights era. His chronology revealed the impact of investment in science discovery and exploration on economic growth and on levels of public science engagement and awareness.

Dr. Isa Zimmerman, former Senior Fellow at the University of Massachusetts Donahue Institute and former teacher and K-12 and university administrator, described some of the Readiness Project's recommendations most relevant to STEM education. Dr. Zimmerman has been instrumental in promoting STEM initiatives in Massachusetts and was a participant in the development of the Readiness Project. She noted that teachers in general and STEM teachers in particular were, unfortunately, conspicuously unrepresented among the Readiness Project committees. She emphasized the possibility of leveraging information technology to support innovations in teaching and learning, strengthening connections among the Commonwealth's education and economic development efforts, and accelerating the entry of high-quality teachers into public high schools, particularly in high-needs districts. She also supported the Readiness Project's recommendation to establish a Readiness Science and Math Teaching Fellowship to increase the supply of qualified math and science teachers. The Readiness Project background information was particularly relevant as it became clear that many of the STEM teachers participating in the meeting, in the Commonwealth in general, have not yet been informed of its existence.

Ms. Caroline Goode, Director of the Massachusetts chapter of Building a Presence for Science, spoke about the burgeoning availability of science education programs available to teachers and the general public in Massachusetts. She pointed out the need for quality teacher education and called for a push to encourage more education students to choose science as their specialty. Ms. Goode also spoke about how the public's embrace of education programs such as those offered by the

McAuliffe Center at Framingham State College is a hopeful sign for improvement in science education in the Commonwealth.

Ms. Sylvia Cooley, a biology teacher at South Hadley High School, spoke about the joys and challenges of being a science teacher in Massachusetts. Ms. Cooley reported that many school districts share a common set of challenges in STEM education, including reduced science classroom time owing to the demands of "teaching to the (*MCAS*) test", limited access to the technology and equipment required to provide sufficient hands-on science experiences, and a decrease in the number of teachers willing to teach science. Even with these limitations, however, Ms. Cooley showed how she is able to translate her energy, creativity, and enthusiasm into an exciting and transformative science experience for her students. She described her class in forensic science, which leverages the students' existing enthusiasm for crime scene television dramas, such as CSI and Numbers, to engage them in learning and applying STEM principles that make such crime detection possible. This class has become a high point for many of her students and also generates considerable enthusiasm from outside the classroom.

Ms. Mary Ann DeMello, Assistant Superintendent for Instructional Services and Support in the Weymouth Public School system, as well as a veteran classroom teacher, discussed the growing chasm between the technological aptitudes of teachers and those of their students. She noted that students are immersed in a digital world of texting and twittering and other activities not embraced by many of the adults in their lives, including their teachers. Ms. DeMello urged teachers to take advantage of these technologies and employ them as tools to connect more effectively with students. A classroom race to find online answers to science questions might result in a discussion of how to search effectively for information, how to assess its accuracy, as well as learning about the topic. She also discussed the disconnect in awareness and communication among government agencies, school boards, teachers and parent-teacher organizations that leads to ineffective management of education issues. Ms. DeMello urged the forum participants to find mechanisms to identify and promote the shared interests and goals of such a diverse audience, for the good of the students.

Following the formal presentations, the participants were divided into working groups, each charged with addressing a subset of STEM education reform topics. Each working group engaged in several hours of frank discussion regarding their topic area and identified a set of action items that met the forum's objectives. Scribes for each group kept detailed notes on the discussion. At the end of the day, the participants reassembled and a representative from each working group presented its recommendations. MAS President, Dr. Margaret Riley, and Governing Board Chair, Robert Lichter, were then charged with producing a draft document that incorporated the discussion from each working group into a summary report. The participants were invited to view the draft document to ensure that it accurately reflected their views. The final document was approved by the Governing Board of the Massachusetts Academy of Sciences.

The following is a summary of the discussion and recommendations that emerged from each working group.

EARLY CHILDHOOD INTERVENTION AND ASSISTANCE

Children have a natural curiosity about themselves and their world that makes them ideal scientists. They love to investigate, they excel at taking things apart and putting them back together, and they won't hesitate to ask questions. Our primary job in creating opportunities for early childhood exposure to science is to create a safe environment for youngsters to facilitate their natural exploration instincts. As one participant put it, we need to "help the adults allow kids to get messy, do the hands on work, and not just shut them down." Indeed, as another noted sardonically, "Science is what kids do until we teach them how to do science."

Although the classroom is certainly critical for engaging children in science, and schools continue to need support, children spend far more time outside the classroom than in it. Indeed, a significant body of research underscores the importance of creative use of after-school and out-of-school time[2, 3]. Thus, our goal must be to make science an integral part of children's daily lives, included in the broad array of activities in which they take part, such as music, art, and athletics, and other games.

To reach that goal, we need also to embrace parents, guardians and caregivers—especially those who are not already connected in some way with science—and provide them accessible information and programs that are meaningful to their varied communities. These may include television and radio shows, movies, web sites, games, books, museums, home-based science activities, events, and other resources. The Commonwealth is fortunate in having available a wealth of appropriate materials, television and radio shows and other activities that adults can tap to inspire and excite kids about science. A sample of these resources is provided in BOX 1.

BOX 1

Boston Children's Museum - Founded in 1913, the BCM exists to help children understand and enjoy the world in which they live. It is a private, non-profit, educational institution that is recognized internationally as a research and development center and pacesetter for children's exhibitions, educational programs and curriculum.

PBS Kids Go! - A free web site that provides preK-12 resources to support learning at school.

Zoom – A PBS daily interactive television series that challenges five- to eleven-year-olds to "turn off the TV and do it!" Based on the original hit series from the 70's, ZOOM is packed with science experiments, recipes, plays, games, jokes, chats, poems, and volunteer ideas, all sent in by viewers, and offering a wealth of activities for kids to do by themselves, with friends, or with their parents.

(Continued)

BOX 1 ***(Continued)***

The Discovery Museums - Located in Acton MA, this collection of museums inspire enduring curiosity and love of learning through interactive discovery, hands-on inquiry and scientific investigations. The Museums have extensive school programs, which include museum field trips, group visits, and classroom outreach.

Museum of Science - One of the nation's premier science museums, the Boston Museum of Science sponsors a variety of exhibits, demonstrations, outreach activities and summer programs.

Demographic shifts in the United States are mirrored in the Commonwealth. That science activities be connected with the daily experience of children is especially important for populations underrepresented in science, especially African Americans, Latinos/Hispanics, and American Indians, but also including girls and persons with disabilities. A model for success was described during the discussion: The Science Club for Girls. A federation of independent but connected groups, the ca. 10 chapters around the Commonwealth are organized by parents, community groups, houses of worship, and others, who receive guidance from the organization in creating activities that specifically appeal to girls. This model could be applied to other populations.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate the creation of an annotated list of all science education and outreach resources in the Commonwealth. Users should have the opportunity to rate the resources they explore and provide written reviews and comments to help guide future users.*

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate the creation of a model system for identifying ways to integrate science into everyday life. This might include online models for how to set up science clubs and suggestions for parents/caregivers on how to recognize science everywhere. The site should also provide a forum for parents and teachers to discuss what works and what doesn't.*

Unfortunately, not all families engage in science based activities and discussions and many adults approach science with anxiety and trepidation. It is imperative that we provide additional avenues to encourage children's science engagement outside of the home setting. Targets could include day care centers, libraries, community centers, parks, and houses of worship. These settings need support for strengthening their science offerings and assistance in overcoming any unease with science, so that at the very least children can be helped to recognize science and scientific behavior (asking a question, testing an idea) even in simple observations they make. Numerous materials are available to help these facilities engage in science based activities and discussions and samples are provided in BOX 2.

BOX 2

Kids Science Experiments - A web site full of fun, easy and exciting hands-on experiments. These simple, safe and easy to follow science experiments can be achieved with everyday materials and recycled items found around your house.

Science Club for Girls - The mission of Science Club for Girls is to increase the self-confidence and science literacy of K–12th grade girls belonging to groups that are underrepresented in the sciences, through free, after school programs that provide experiential learning, mentorship, and leadership opportunities.

KinderArt Littles Science - A web site devoted to providing free science ideas and activities for preschool teachers and caregivers.

Quirkles - A book series that employs 26 imaginary scientists that help children everyday, all over the world, develop a love and appreciation for science. They offer a fresh new way to integrate literacy and science at school, for educational programs, or at home.

In addition to resources described above, caregivers need well-trained volunteers who are willing to instruct them in modern approaches to engaging youngsters in science, and work with the students to inspire their nascent love of science. The commonwealth needs to extend current efforts to engage professional and retired STEM scientists and educators to help parents/caregivers engage children in science activities.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate the creation and training of a volunteer core of STEM professionals to work with parents, teachers and other caregivers to find ways to bring science into the lives of children. The MAS web site should feature podcasts and other audio-visual tools that show caregivers how to engage children in science experiments or take them outside to explore nature. The MAS could provide certification for these volunteers, following a training period.*

Participants in the discussion acknowledged strongly that any efforts directed to children need to be properly evaluated. The difficulty in doing so was acknowledged; at the same time, well developed methods for meaningful evaluation have emerged from the social sciences, including pre- and post-experience tests, interviews and focus groups, and third-party observations of behavior. Key to a good evaluation is the participation of well-educated and experienced evaluators.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate the creation of a STEM evaluation referral service to permit easy access to appropriate evaluation tools and advice.*

Whether in or out of school, it is important to recognize and deal with the barriers that can inhibit children's profound involvement with science. In addition to inadequate access to the types of resources discussed here, the single barrier that the participants identified most strongly was the

Massachusetts Comprehensive Assessment System (MCAS). Several described how so much of out-of-school time is used to prepare for this evaluation, on which so much rides for both the students and the schools.

RAISING THE ACHIEVEMENT LEVELS OF ALL STUDENTS

The Massachusetts state legislature passed the Education Reform Act in 1993 that increased state aid to local districts, required many districts to spend more money per child, called for new accountability standards, and opened up the educational marketplace to charter schools[4]. The outcome has been some notable successes such as the improved state curriculum standards, which are rated the very best in the nation[5]. Even the controversial MCAS tests have provided an overall sense of achievement in the public school education system, with the great majority of students achieving passing scores[6].

Unfortunately, not all students fared as well in MCAS evaluations. The State's low-income and minority students have made only "moderate progress" in terms of MCAS scores over the past 4 years[6]. The gap in performance between white and Asian students, compared with African American and Hispanic students remains pronounced. And the drop out rate for inner city youths remains over 20 percent[7].

Students in the class of 2010 are the first to face the state-mandated MCAS science test as a graduation requirement[8]. Given that the State is prepared to require all students to pass the MCAS Science test, it should also be required to provide a level playing field for all students in which to learn science, including minimally equipped laboratories, reasonable access to computers and funds to supply materials for science experiments. Tax increases, such as a one-cent sales tax described below to fund technology access and science teaching in the Commonwealth, could be an avenue. The MAS can, and should, play a central role in advocating for minimal school science laboratory technology resources.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate, in coordination with the Massachusetts Association of Science Teachers and the Massachusetts Department of Elementary and Secondary Education, opportunities to engage STEM professionals in discussions across the state to identify the minimal resources required per student to effectively teach science.*

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate the work of legislators, industry, and the community to allocate funds required to ensure that all schools have the identified minimal set of resources.*

Let us return to the observed gap in science performance of white and Asian students compared with African American and Hispanic students. Race, language, sex, or economic circumstances must not be a factor in determining who receives a good education in science. Many of these lower-performing minority students are located in inner cities and in school districts with few resources available to the students. Meeting this challenge will require new solutions, targeting the unique hurdles faced by these students. Further, the solutions must be applied to vocational, general, and college preparatory student bodies. Numerous programs already exist, ranging from national to local targets and a sample is provided in Box 3.

BOX 3

SEDL - A private, nonprofit education research, development, and dissemination corporation whose mission is to solve significant problems facing educational systems and communities to ensure a quality education for all learners. SEDL's primary efforts are in improving school performance, strengthening teaching and learning in content areas, integrating technology into teaching and learning, involving family and community in student learning, and connecting disability research to practice.

The Benjamin Banneker Institute - was founded, with support from Congress, to combine many of the existing initiatives addressing low performance and participation rates of African Americans in STEM professions and fields of study. The Institute works to identify, create, and/or support pilot projects designed to demonstrate the effectiveness of the most promising approaches.

Society for the Advancement of Chicanos Native Americans in Science - seeks to encourage Chicano/Latino and Native American students to pursue graduate education and obtain the advanced degrees necessary for science research, leadership, and teaching careers at all levels.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate, working in concert with the Massachusetts Teachers Association, the Massachusetts Parent/Teacher Association and local and state legislature, that all communities have equal access to a minimal set of technology and laboratory facilities, perhaps through the creation of a one-cent sales tax.*

CREATING CONDITIONS TO SUPPORT EXCELLENT TEACHING

The more teachers share in shaping science education reform and the more help they are given in implementing agreed-upon changes, the greater the probability that they will be able to implement the improvements successfully. Teachers understand the knowledge level of their students, the school cultures, and the time and resource limitations they uniquely face. Perhaps most important, if teachers are not convinced of the merit of proposed changes, they are unlikely to embrace them.

One of the starting points for this discussion was an acknowledgement of the numerous and varied professional development resources available to Commonwealth science teachers, including many programs in and run by industry. Even a small sample of these resources quickly reveals the breadth and richness of the offerings. A sample of such resources is provided in Box 4.

BOX 4

Massachusetts STEM Collaborative - Its mission is to dramatically increase student interest in, and preparation for, careers in science, technology, engineering, and mathematics; and to increase the number of highly-qualified teachers in math, science, technology and engineering.

UMass STEM Institute - The University of Massachusetts seeks to be the Commonwealth's resource for improving K-16 STEM education by providing leadership, curriculum development (both K-12 and public higher education), higher education and K-12 teacher preparation, research, and STEM policy development and advocacy.

Biotechnology Institute - This national biotechnology education organization provides a professional development program for biotechnology teachers from low-income communities in Massachusetts. The program brings state-of-the art biotechnology education to middle school and high school students and better prepares them for careers in the biotechnology industry.

Worcester Polytechnic Institute's Professional Development Opportunities for Middle School Teachers – WPI offers a variety of professional development opportunities for middle school teachers. All of these opportunities are free of charge, and offer some form of stipend.

Even with such a varied and rich source of professional development resources, many science teachers in the Commonwealth report that they find it (1) hard to find the right resources to meet their needs, (2) challenging to find or create the time required to participate in professional development, and (3) hard to incorporate what they learn into the already demanding curriculum requirements of their classes and the limited time they are able to devote to science.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate hosting and maintaining a web site providing an up-to-date list of all professional development resources available to STEM teachers in the Commonwealth, each giving the target audience, a brief synopsis of the program, contact information and links to the program material. In addition, a "stamp of approval", should be assigned to each item, based upon teachers' reviews. The site should also host a Science Resource News Blog, at which teachers will be able to describe their experiences, direct other teachers to the more-compelling programs, or request help finding resources. The site should provide a regularly updated list of all funding resources to enable more teachers to participate in career development activities. An alert system should be devised for interested teachers, through which new resources and funding opportunities will be rapidly disseminated.*

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate the sharing of professional development resources across districts and pooling of resources to provide more professional development opportunities. MAS should advocate for the importance of professional development for STEM teachers and should provide letters of support for teachers to help them obtain release time to pursue further education.*

The working group noted concerns centered on the varied levels of access to technology and laboratory equipment in schools across the Commonwealth. Many districts lack access even to minimal resources for teaching science for the 21st century. Participants suggested that MAS could interface with science-based industry to promote higher levels of equipment and technology donations. Several existing highly successful programs might serve as models of how industry can become more involved in meeting these needs. A sample of these programs is provided in Box 5.

BOX 5

Thinkfinity.org - Verizon Foundation's free, comprehensive web site containing more than 55,000 educational resources, including standards-based, grade-specific, K-12 lesson plans, online educational games, videos, and other materials provided in partnership with many of the nation's leading educational organizations.

DesignLab - UMass Lowell is pioneering the development and distribution of invention kits that middle schools can use to set up after school science and technology enrichment programs. The kits, coupled with a web-based support system and instructional DVDs, will help the teachers provide compelling and timely access to scientific experimentation. This project is supported by a grant from Mark Gelfand, co-founder of Intex Solutions, Inc.

Although these resources have enabled a higher level of science instruction for numerous Massachusetts students, many students still have limited or no exposure to hands-on science. In a state with a significant STEM-based economy it should be possible to ensure that all children have access to the learning tools required to produce scientifically aware and engaged citizens. Clearly, the relevant industries can and should be called upon to do more in this area.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate creation of a network of industrial donors to help meet the laboratory and technology needs of public schools across the Commonwealth. MAS can provide the interface required to link the appropriate industries and school districts and to ensure that the partnerships are nourished and maintained. MAS should also engage industrial and university research scientists to help science teachers learn how to use and operate the equipment and technology and incorporate these resources into their curriculum requirements. Although numerous industries already contribute time, resources and funding, a more coordinated approach will leverage their existing contributions to reach more of the Commonwealth's future potential scientists.*

Participants also discussed challenging the Commonwealth to initiate a one-cent sales tax to equip schools with adequate technology. Similar to successful initiatives in Florida and South Carolina that provide every student with access to a laptop, this approach would ensure that schools have more equitable access to available resources[9, 10].

Several teachers in this working group reported that they are required to focus significant effort on improving math and reading performance, in large part because of MCAS requirements. One outcome is that there are often few resources and little class time available for science education. MAS might be able to help put the spotlight back on science by advocating for the critical need for science education. Funds to provide more released time for teachers to participate in professional development were strongly supported.

> **RECOMMENDATION**: *The state of Massachusetts needs and the MAS can facilitate developing a long-term strategy to advocate for science education reform at the level of the Governor's office and State and local legislators. In consultation with science teachers and educators, through working groups and conferences, MAS should help to define the minimum amount of class time required for science education. Further, it should create a list of the recommended types of technology and equipment needed to translate this minimal time into the greatest impact on the student's engagement with and understanding of science. MAS should also initiate an effort to convince school administrators, legislators and parents of the central role science serves in Massachusetts and the need for a scientifically literate workforce.*

One further area of concern discussed by this working group involves the inadequate number of teachers choosing to specialize in STEM teaching. In part, the problem is engaging future science teachers during their college experience. Presentations and informed discussions with inspiring scientists and science teachers are mechanisms, as well as real research experiences, that might help to make science more appealing and less intimidating to interested teachers in training. Recognition of science teachers' efforts in developing and maintaining their expertise is essential as well. Technology changes rapidly and a teacher must be willing to commit to life-long learning experiences to remain current. Those teachers willing to commit to such professional development should be honored in a meaningful and visible manner.

> **RECOMMENDATION**: *The state of Massachusetts needs and the MAS can facilitate a series of awards to support excellence such as a Science Teacher Excellence Award. In concert with science teachers and professional educators, the MAS will develop a set of requirements that will be judged on an annual basis. Winners of the award would be honored at the MAS Annual Meeting In an appropriate manner. These teachers would be expected to promote science education and professional development. Further, such award programs should be developed to honor the efforts of school administrators, parents/caregivers, industry and local government officials who create and implement solutions to the complex challenges.*

PREPARING TODAY'S STUDENTS FOR TOMORROW'S STEM WORKFORCE AND ITS LEADERSHIP

It is clear that economic strength in the Commonwealth depends on a scientifically engaged and aware citizenry[11]. STEM occupations comprise a substantial fraction (~13%) of the workforce[12]. In fact, most of the fastest growing jobs are STEM occupations or STEM-supported positions. STEM industries also generate jobs in other fields such as law, business and other professional services. Indications are that filling STEM positions is becoming increasingly difficult[13]. Several STEM-related occupations are experiencing high job-vacancy rates[14]. At the same time, there are gaps in STEM performance across subgroups of the population. Black and Hispanic students scored far lower (~50%) in tenth grade mathematics assessments in 2006[15]. So, while African Americans and Hispanics comprise an increasing fraction of the workforce, and the need for STEM workers is similarly increasing, it is clear that efforts to better educate minority students in STEM topics must become a priority.

This challenging goal requires input from many avenues, including the science industries themselves, parents and teachers, as well professional educators and teachers. Few high school students, much less their parents, could describe what a biotechnology scientist does at her lab bench, the kind of tasks performed by an electrical engineer, or the training required to design computer science tools such as "twittering" or "texting". The image of the nerdy scientist remains fixed in society, with his pencil-filled pocket protector and calculator strapped to his belt; this caricature of a scientist invokes images of a person with few social graces, many years of education, and little ability to communicate with non-scientists. It is time to change this perception and educate the public regarding the exciting and challenge careers that await the well-trained scientist.

This working group immediately focused its attention on the challenge of reaching and informing the varied, culturally and economically diverse target audience that is the Commonwealth's population. The web and television effectively help to level the playing field, such that even children from economically challenged families or inner-city neighborhoods can explore nature, our planet's ecological future, molecular and atomic structure, or the grandness of the universe. Box 5 provides a list of some of the more popular television and radio shows devoted to science outreach and education.

One of the more successful mechanisms for engaging the interest of high school and university students in STEM careers involves exposure through internship programs, job share opportunities, and career mentoring programs. A variety of such mechanisms exist in the Commonwealth. A sample of these is provided in Box 6.

BOX 6

Job Shadow - Some school districts in the State support a nationwide mentoring initiative that pairs students with professionals in the workplace. The goal is to provide high school students with a behind the-scenes look at what a business does and how they do it.

Job Share - This highly successful intern program involves a number of young students sharing one intern position. The students attend school 4 days per week and then spend the 5th day at work. This exposure at an early age develops confidence and interest in the students and provides a stream of future employees
for the industries that participate.

Stand and Deliver - A program promoted by Raytheon and the Lawrence School System that pairs individuals from industry with students for after school one-on-one mentoring/tutoring activities.

LifeWorks - This web-based program is provided by the National Institutes of Health Office of Science Education. The goal is to permit students to explore hundreds of difference careers in the life sciences. The site provides interviews with scientists, college and career time line planning tools, and education requirements and salary offerings for over 100 science occupations.

NOVA Science Cafés - An outreach program by WGBH, Boston, which engage a broad and diverse public in dialogue with scientists in casual, non-academic settings like pubs and cafés. Evaluations are showing that the program is succeeding in attracting the young adults who are its primary target audience and even helping to catalyze and connect more grassroots cafés across the United States. This resources
was partially funded by the National Science Foundation. **(Continued next page)**

Youth Astronomy Apprenticeship - An out-of-school time initiative that fosters science learning as an effective way of promoting overall youth development and competitive professional opportunities among urban teenage youth and their communities. Based in Cambridge, Massachusetts, the program is a collaboration between the MIT Kavli Institute for Astrophysics and Space Research, the Smithsonian Astrophysical Observatory, the Timothy Smith Network, and the Institute of Learning Innovation. Over the last two years, YAA urban youth have learned to communicate science to their communities by developing their own plays, museum exhibits, instructional activities, planetarium shows, and marketing campaigns.

Museum of Science – One of the nation's premier science museums, the Boston Museum of Science sponsors a variety of exhibits, demonstrations, outreach activities and summer programs.

Woods Hole Science and Technology Education Partnership - The purpose of this registry is to help local teachers and students connect with people in the community who have scientific knowledge they would like to share in order to help educate. The registry welcomes scientists, technicians, graduate students, teachers and any local community member who has knowledge and enthusiasm to offer a local educator
or student.

Mobile Training Unit - The MTU is operated by the Massachusetts Manufacturing Extension Partnership (MassMEP) and houses 12 computers, a mini-mill, and a mini-lathe. Over 2,000 middle school students in western Massachusetts have visited the MTU and participated in this STEM manufacturing career
awareness program.

Science Club for Girls - SCFG strives for a future in which girls are no longer excluded from a culture that has traditionally favored boys. It endeavors to create a world in which girls feel sufficiently empowered for equal participation in scientific investigations.

In particular, the STEM industry in Massachusetts has developed a successful mechanism, corporate campus academic mentoring, for engaging middle school and high school students in STEM learning[16]. This dynamic has the double impact of a mentor in a STEM

career sharing not only knowledge but excitement for STEM work. Corporate campus academic mentoring is in its infancy. This is an opportunity for the Massachusetts Academy of Science to be an early adopter and promote corporate campus academic mentoring throughout the state.

Participants agreed that MAS can play an effective role in motivating students to consider STEM careers by making existing resources easy to find and accessible to a broader audience. Further, they can coordinate industrial and university volunteers to ensure that each school district has a person to contact for help in career outreach activities.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate a publicity campaign to educate and excite students and parents in the Commonwealth about the diversity of STEM career opportunities available. This could involve providing a central repository for all existing STEM workforce development opportunities on the MAS website, and initiating and overseeing a coordinated industrial/university/school partnership program to match volunteer science mentors with students in their geographic area.*

INFORMAL STEM EDUCATION IN THE COMMONWEALTH

A growing body of research documents the power of informal learning to spark curiosity and engage interest in the sciences. According to the National Science Teachers Association, engaging the public with science results in improvements in science literacy and an increase in the perceived relevance of science and science education in the world today[17]. The impact of informal experiences extends to the social realms by bringing mentors, professionals, and publics together. It puts a human face on scientists and science educators and provides mentors and role models. This “out of the classroom” approach to science education provides an entry into science by people with different backgrounds, levels of education, and learning styles. In fact, informal science education is often the only means for continuing science learning in the general public beyond the school years.

Most initiatives to address these issues are aimed solely at K-12, yet it is well known that parents are key influences in promoting a child’s interest in science. The Education Development Center[18] identified lack of coordination of education initiatives as the single biggest challenge to increasing the number of students who pursue science degrees at university. Fortunately, the world-wide-web brings a diversity of emerging technologies to bear on this challenge. For example, social networks are now acting as *de facto* email ‘exploders’ on a significantly larger scale. In the summer of 2007, for the first time, social networks surpassed email as the most popular category of websites based on the market

share of visits[19]. In fact, the Internet, even with its unfiltered nature, is the only informal education information source that has been steadily attracting larger audiences to science and technology information in the past few years. The internet, together with proven distance-learning technology can provide the capacity to bring together large audiences that would not otherwise easily communicate with each other. It can strengthen the bonds between formal education and outside institutional resources such as museums. And it can aid in forming the bonds of a community of learning. Since the Internet has become an increasingly important information source, it is essential to provide accurate, easy-to-find, interesting, high-quality scientific material—in order to best promote scientific literacy.

The working group concluded that the most important role for MAS in promoting informal science education consists of coordinating the existing resources and advertising and promoting such opportunities to parents, students and teachers.

RECOMMENDATION: *The state of Massachusetts needs and the MAS can facilitate development of initiatives to help bring science into to the mainstream public, including debunking the negative stereotypes of scientists by promoting web based resources, engaging the public in science based social-networking, promoting science-based television and radio show and utilizing its website to feature iMentoring and science cafés, and sponsoring conferences and science fairs that bring science to the community.*

CONCLUSIONS

The Massachusetts Academy of Sciences held a forum on STEM education reform to help inform the Governor's and State Legislator's agenda in this sphere of activity. The forum participants were representatives of the constituencies most affected by reform efforts and the objectives were to identify a set of priorities that will have the greatest and most immediate impact on STEM students, teachers and parents/caregivers, that are suited to the MAS volunteer-based approach to STEM education reform, and that, once accomplished, will have a significant impact on the quality of STEM education in the Commonwealth.

The primary conclusions reached suggest that the Academy can have the greatest and most immediate impact on STEM education reform by identifying and making easily available resources that will engage and excite STEM teachers, students, parents and other caregivers. Further, the MAS should create and organize a STEM volunteer corps, whose mission is to bring these STEM education and outreach resources to the users, to train them in their use and to instill an understanding of the importance of science in their daily lives.

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