Massachusetts Higher Education STEM Faculty: Partnering in the Transformation of STEM Education in the Commonwealth

Organized By:

Massachusetts Academy of Sciences

Massachusetts Department of Higher Education

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Massachusetts Academy of Sciences
Massachusetts Department of Higher Education

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EXECUTIVE SUMMARY

On June 7, 2011, the Massachusetts Academy of Sciences (MAS) and the Massachusetts Department of Higher Education (DHE) co-sponsored a forum on the role of higher education (HE) science, technology, engineering and mathematics (STEM) faculty in achieving excellence in STEM education outcomes for all Massachusetts students. The forum began a conversation that focused on actions that the community of STEM faculty can and should take which will have the most immediate and lasting impact on students and STEM educators. The following three topics were the focus of the discussion:

- Students, as well as many PreK-16 educators and guidance counselors, are often unaware of the breadth and richness of career opportunities afforded through STEM education. How can higher education STEM faculty, personally and through the resources of their institutions, contribute to increasing awareness and interest in STEM careers and illuminate pathways to post-secondary success for a more diverse population of students?

- The retention and graduation rates of STEM major programs, while tracking closely to the rates for all majors, is unacceptably low. We must minimize this leakage from the higher education pipeline, particularly from groups underrepresented in STEM professions, through research-based strategies to improve student success. What actions, based on current research, can faculty lead to improve retention and graduation rates in their institutions? What new research should be undertaken to further address this challenge?

- Educators at all levels (PreK-16) must continually assess the focus of their curriculum to ensure alignment with student learning needs, current education research findings and industry expectations and practices. Higher education faculty engaged in STEM research and education research must be active contributors in this process. What mechanisms and actions can STEM faculty promote in their institutions to improve communication and collaboration with STEM PreK-12 educators, as well as within their own community of research and education faculty?

The HE STEM faculty forum was stimulated by the publication of "A Foundation for the Future: Massachusetts' Plan for Excellence in STEM education (version 1.0)" in September 2010 by Massachusetts Lieutenant Governor Timothy P. Murray and the Governor's STEM Advisory Council. This plan articulates quantifiable outcomes in five cornerstone goals:

- Increase student interest in STEM,
- Increase STEM achievement of PreK-12 students,
- Increase the percentage of students who demonstrate readiness for college level study in STEM fields,
- Increase the number of students who graduate from a post-secondary institution with a degree in a STEM field, and
- Increase the number/percentage of PreK-16 STEM classes led by effective educators.

Following several plenary presentations, working groups tackled each of the aforementioned topics and produced a draft set of initiative and policy recommendations, which were considered in plenary at the end of the forum. The working groups included PreK-16 educators and out-of-school educators; graduate and undergraduate students, school district and higher education administrators; policy makers; industrial and academic scientists; and representatives of STEM education organizations.

These recommendations are summarized below with the expectation that working groups of higher education faculty will review, refine, and ultimately implement them at institutions throughout the Commonwealth.

SUMMARY RECOMMENDATIONS

The following recommendations are proposed for consideration by HE STEM faculty leading to actionable strategies within Massachusetts public and private HE institutions. In many cases these recommendations suggest institutional changes that STEM faculty must propose and champion within their home institutions.

STUDENT INTEREST AND AWARENESS

- **RECOMMENDATION.** Set up a broker system to connect STEM constituencies to one another, focusing on STEM teachers, students, researchers and non-profit organizations, and charge it with amassing all available STEM outreach resources in one online location.
- **RECOMMENDATION.** Create a program to attract the diversity of HE faculty (active and retired), staff, and graduate/undergraduate students and postdoctoral fellows to engage in STEM outreach.
- **RECOMMENDATION.** Promote and expand the existing STEM outreach programs that engage retired HE faculty as STEM mentors for PreK-12 students.
- **RECOMMENDATION.** Identify mechanisms to incentivize HE research scientists to engage in STEM outreach programs, which result in longer-term mentoring relationships between the HE researchers and PreK-12 students.
- **RECOMMENDATION**. Create a STEM career marketing campaign to advertise the diversity of STEM professionals in the Commonwealth and the wide variety of career opportunities available.
- **RECOMMENDATION**. Engage the diversity of STEM professionals in STEM outreach to meet the needs of the diversity of the PreK-16 student body.
- **RECOMMENDATION.** Research and evaluate existing models of successful STEM outreach.

- **RECOMMENDATION.** Develop a more defined structure to STEM outreach experiences by providing instruction and guidance for those who participate.

STEM STUDENT RECRUITING, RETENTION AND GRADUATION RATES

- **RECOMMENDATION.** Create a replicable framework for bringing research experiences to PreK-12 students in lower socio-economic school districts.
- **RECOMMENDATION.** Increase participation of all PreK-12 students in science fairs.
- **RECOMMENDATION.** Urge PreK-12 students and their teachers to consider multi-year STEM research projects to permit students to take full ownership of the projects, to experience improvements in their abilities, and increase the depth of their research experiences.
- **RECOMMENDATION**. HE faculty should identify mechanisms that would enhance their involvement and influence, both at the local and state levels, in community policy discussions dealing with STEM education.
- **RECOMMENDATION**. Create of a more formalized mechanism to promote higher levels of equipment and technology donations by Colleges and Universities to PreK-12 STEM classrooms.
- **RECOMMENDATION**. Create more opportunities for inquiry-based, project-based, and laboratory-based learning for the entire STEM PreK-16 student population.
- **RECOMMENDATION.** Higher Education faculty should engage in frank discussions about the obstacles many college students face in pursuing STEM majors and how to remove them.
- **RECOMMENDATION.** Create a more structured relationship between those who work in community colleges and those who work in universities to ensure students can more seamlessly move between higher education options.
- **RECOMMENDATION.** Engage in a statewide survey of undergraduate students to assess the reasons why they do or do not choose to study STEM topics.
- **RECOMMENDATION.** Create a leadership program to bring undergraduate STEM majors into the PreK-12 classroom.

STEM EDUCATOR EFFECTIVENESS

- **RECOMMENDATION**. Create programs at universities that will support HE faculty in meeting their federal funding requirements to engage in outreach.
- **RECOMMENDATION.** HE institutions should create opportunities for teachers in training to meet inspiring STEM role models, to gain research experience, and to visit effective PreK-12 STEM classroom settings.

INTRODUCTION

In September 2010 Massachusetts Lieutenant Governor Timothy P. Murray and the Governor's STEM Advisory Council released a plan for reforming STEM education in the Commonwealth, entitled: "A Foundation for the Future: Massachusetts' Plan for Excellence in STEM education (version 1.0)." The plan identifies five key goals and provides benchmarks to work towards over the next five years:

- Increase student interest in STEM,
- Increase STEM achievement of PreK-12 students,
- Increase the percentage of students who demonstrate readiness for college-level study in STEM fields,
- Increase the number of students who graduate from a post-secondary institution with a degree in a STEM field, and
- Increase the number/percentage of STEM classes led by effective educators, from PreK-16.

Review of the report suggested that this strategic plan offered an opportunity to identify specific areas in this complex and challenging problem in which one key stakeholder, HE STEM faculty, could provide both guidance and action in reaching the goals identified. These HE faculty educators and researchers interact daily with undergraduate students who are the product of the state's PreK-12 school system: they teach, guide, and mentor these students, critically influencing the decisions that will impact their success in college and careers.

Until now, HE professionals (scientists, faculty members, and administrators) have played a relatively modest role in addressing PreK-12 STEM education reform in Massachusetts. This is surprising, given the strength of our state's HE systems and the number and diversity of its STEM faculty. It is imperative that the HE faculty and administrator resources be fully engaged in Massachusetts STEM education reform efforts. Higher education faculty can, and must, work together with their fellow stakeholders (PreK-12 teachers, non-profit leaders, and scientists in industry) to address the complex challenges of STEM education reform in the Commonwealth.

To help inform its agenda in this sphere of activity, the MAS and the DHE organized an invitational forum on STEM education reform, where representatives of the HE community were encouraged to participate and begin the process of formulating a strong leadership voice. 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 engage HE faculty in identifying the challenges and proposing solutions, and that, once accomplished, will have a significant impact on the quality of STEM education outcomes in the Commonwealth.

Representatives of several stakeholders in this initiative coordinated the organization of the forum. This Steering Committee was tasked with creating a participant list, with care taken to ensure that diverse experiences, backgrounds, points of view, ethnicities and genders were represented. The attendees included teachers and administrators from public and private schools, undergraduate and graduate students, faculty and administrators from public and private universities, representatives from not-for-profit

STEM formal and out-of-school education and outreach organizations, and STEM 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 "Foundation for the Future" plan and specific needs for PreK-16 STEM education reform in the Commonwealth:

- Increasing student interest in STEM,
- Increasing PreK-12 student achievement in STEM,
- Increasing the percentage of students who demonstrate readiness for college level study in STEM fields,
- Increasing the number of students who graduate from a post-secondary institution with a STEM degree, and
- Increasing the number of PreK-16 STEM classes led by effective educators.

The forum was convened on June 7, 2011. The approximately 120 attendees represented a broad spectrum of stakeholders from the various regions of Massachusetts. A plenary session consisted of a series of brief informational presentations to provide a context for subsequent discussion.

Dr. Margaret Riley, President of the MAS and professor of biology from the University of Massachusetts, Amherst, described the role of the MAS in a HE and PreK-12 partnership. Mr. David Cedrone, Associate Commissioner of the Massachusetts Department of Higher Education and Executive Director of the Governor's STEM Advisory council, spoke about Massachusetts's plan for excellence in STEM education. Finally, Dr. Isa Zimmerman, member of the STEM advisory council, spoke about the need for a voice for PreK-12 students and educators.

Following these introductory remarks a panel session was convened to discuss the question: "How can PreK-12 and HE faculty and administrators work together to recruit, retain, and graduate STEM students?" Panel members included Dr. Robert Dorit, Professor of Biological Sciences at Smith College; Dr. Stephen Hegedus of the UMass Dartmouth Kaput Center for Research and Innovation in STEM Education, and Dr. Linda Grisham, Director of the Center for Teaching, Learning, and Technology Innovation at Massachusetts Bay Community College. Dr. Antoinette Hays, President of Regis College, moderated the discussion.

The participants then chose to join one of five working groups, identified above, each charged with addressing a subset of STEM education reform topics and identifying immediate action items, as well as longer-term goals and "marketing messages" for further discussion and planning. This document summarizes the recurring themes that emerged as participants engaged in frank and eloquent discussions. At the end of the day, the participants reassembled and a representative from each working group presented its recommendations.

Dr. Anne Pycha, science writer for the Massachusetts Academy of Sciences, was charged with producing a draft document that incorporated the discussion from each working

group into a summary report. The participants were then invited to view the draft document to ensure that it accurately reflected their views. The following is a summary of the discussion and recommendations that emerged from each working group.

INCREASING PREK-12 STUDENT INTEREST IN STEM

Economic strength in the Commonwealth depends on a scientifically engaged and aware citizenry. STEM occupations comprise a substantial percentage of the Massachusetts' workforce. In fact, most of the fastest growing job sectors are STEM occupations or STEM-supported positions. STEM industries also generate jobs in other fields such as law, business and other professional services. It is becoming increasingly challenging to fill STEM positions and several STEM-related occupations experience significant job-vacancy rates, even in this difficult economic period. At the same time, student interest and readiness to pursue post-secondary STEM majors are lagging.

The disconnect between the need for an increased pool of STEM professionals and a lagging interest and readiness of PreK-16 students to pursue STEM careers requires prompt and sustained attention. 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, despite the fact that most of them are quite familiar with "Tweeting" and "Texting". It is also important to note that a strong foundation in STEM knowledge and skills is essential to many so called "Middle Skill" jobs that require more than a high school education but less than a four-year HE degree. One need only look at the complex service requirements of today's automobiles or the floor of today's advanced manufacturing machine shops to understand that STEM is essential in careers that might not have been considered STEM-critical only a few years ago.

It is crucial to educate the public regarding the exciting and challenging careers that await the well-trained scientist. This working group focused its attention on reaching and informing the culturally and economically diverse student population of the Commonwealth. They noted that STEM researchers in HE traditionally have little or no contact with the PreK-12 environments, and may have limited experience communicating with and engaging this community. Similarly, educators in PreK-12 settings often have little or no contact with HE faculty, and may lack the necessary background and/or time to understand the more advanced aspects of current scientific research. A broker system, implemented as a web 2.0 community, could help to address these problems and also help to create connections among the community of Massachusetts STEM stakeholders.

The broker system should promote and support the development of a STEM community that spans PreK-12, out-of-school and non-profit education organizations, HE, industry, and government. It should leverage social networking technology and concepts in order to promote collaboration at all levels: between STEM researchers and educational researchers, between academic and industrial researchers, between higher education faculty and PreK-12 educators, and between scientists and students at all levels. The goal is to build a "meta" community that truly unites all the smaller, embedded STEM communities of Massachusetts.

One of the more successful mechanisms for partnering middle and high school students with professional scientists is the Corporate Campus Academic Mentoring Program created by Raytheon in Massachusetts. Middle and high school students are exposed to STEM careers through internship programs, job share opportunities, and career mentoring programs. These STEM professional mentors share not only their knowledge but also their excitement for STEM work with the students. This program is in its infancy, however, and a major limitation is lack of coordination between industrial volunteers and the school districts. The STEM broker system described above could address this challenge directly and bring HE STEM faculty more directly into the STEM mentoring role.

- **RECOMMENDATION.** Set up a broker system to connect STEM constituencies to one another, focusing on STEM teachers, students, researchers and non-profit organizations, and charge it with amassing all available STEM outreach resources in one online location.

There are several examples that such a broker system could follow, such as the Directory of STEM Resources created by the Southeastern Massachusetts STEM Network, the Connect a Million Minds Connectory created by Time Warner Cable, the Resources Page created by IKZ Advisors, the Educational Resource Center created by the Massachusetts Biotechnology Education Foundation, the STEM Resources page created by the Massachusetts STEM Initiative, and the Project ENGAGE website created by the Massachusetts Academy of Sciences.

Another discussion point focused on the fact that the outreach opportunities need not consist of classroom or laboratory visits, although these were certainly the most common types discussed at the meeting. Where appropriate, the broker system could assist scientists with other approaches, such as online demonstrations, science journalism for PreK-12 audiences, children's books, podcasts, and so on.

Members of the forum noted that STEM outreach programs should target the diversity of the HE community, including faculty (active and retired), staff and graduate/undergraduate students. In fact, many attendees mentioned that graduate students and post-doctoral researchers often make excellent ambassadors for science. Compared to tenure-track faculty, they have fewer demands on their time, tend to come from more diverse population pools, and are often closer in age and experience to PreK-12 students. Another pool of potential mentors is the community of retired STEM faculty, which already has a strong mentoring role, coordinated by the Retirees Enhancing Science Education through Experiments and Demonstrations (RE-SEED) Program, a program based at Northeastern University that has trained over seven hundred retired engineers and scientists in fourteen states to assist PreK-12 teachers and to serve as mentors to their students.

- **RECOMMENDATION.** Create a program to attract the diversity of HE faculty (active and retired), staff, and graduate/undergraduate students and postdoctoral fellows to engage in STEM outreach.

- **RECOMMENDATION.** Promote and expand the existing programs that engage retired HE faculty as STEM mentors for PreK-12 students.

The topic of sustained mentoring relationships came up at several points in the meeting. Educators would like to see scientists who are willing to meet with students more than once, perhaps developing a mentoring relationship over the course of a year, or even longer. The broker system could potentially use email and/or social networking to keep scientists and students in touch with one another.

- **RECOMMENDATION.** Identify mechanisms to incentivize HE research scientists to engage in STEM outreach programs, which result in longer-term mentoring relationships between the HE researchers and PreK-12 students.

Members of this working group expressed concern about the messages that young people receive about science and math from their peers, their teachers, and the media. Many students believe that science is a set of facts, established by a group of historically distant people, which they must now memorize and regurgitate. Nothing could be further from the truth, and we must counteract this belief in order to make scientific thinking part of young people's daily lives. The act of doing science means bringing yourself to the edge of the known world. It means making yourself comfortable with *not* knowing. It means emphasizing and formulating the right questions, before worrying about the right answers. Everyone has had a frustrating experience with math or science in the past: the tough exam, the overwhelming course, the intimidating instructor, or the indecipherable problem sets. Experiences like this are normal, and they do not mean that you "can't" do science.

Several argued that HE stakeholders must develop a new set of messages about STEM and find effective ways to deliver them. The key marketing messages, which HE can help to deliver, accelerate, and improve upon, include:

- Science achievement in school can lead to interesting and satisfying careers.
- People who engage in science are of both genders and every ethnicity.
- Science is not already "figured out"; there are enormous opportunities to create, explore, invent and discover.
- Scientists are not people who know everything; they just happen to know a lot about certain parts of science.
- You can practice science even if you have had a frustrating experience with it in the past.
- You can practice science even if you have struggled with math or chemistry or physics.
- You can practice science at many professional levels from laboratory or industrial technician to academic research scientist.

- **RECOMMENDATION**. Create a STEM career marketing campaign to advertise the diversity of STEM professionals in the Commonwealth and the wide variety of career opportunities available.

The topic of diversity was addressed repeatedly throughout the forum. It is important for students in PreK-12 classrooms to meet scientists who come from diverse backgrounds; so that they develop a sense that "people like me" can do science. It's also important that visits from scientists meet the needs of all of the students in the classroom, including ESL, accelerated, and special education students. PreK-12 educators could use the broker system described above to develop a plan that would achieve these goals over the course of a given school year.

- **RECOMMENDATION**. Engage the diversity of STEM professionals in STEM outreach to meet the needs of the diversity of the student body.

On a more advanced level, the broker system could help *structure* the outreach experience so that it is more satisfying for all involved. It could provide communication scripts and pointers for scientists who intend to visit classrooms so that they can connect with the PreK-12 student population in a pedagogically meaningful way. It could provide video and social media platforms for scientists to communicate virtually with students, and interact with them in online Q&A forums. It could provide information about career trajectories; many scientists who work in academic settings aren't necessarily knowledgeable about industry careers in science, but PreK-12 students and teachers are bound to ask them questions about this. We can address this challenge by bringing industry partners directly into the social network. The broker system could also provide topic primers for students and teachers, so that they are prepared to understand the specific projects that the scientist works on and ask questions about them.

- **RECOMMENDATION.** Research and evaluate existing models of successful STEM outreach.

- **RECOMMENDATION.** Develop a more defined structure to STEM outreach experiences by providing instruction and guidance for those who participate.

Several programs targeting mentor training already exist, such as the Mass Mentoring Partnership. However, there is a relatively minor focus on STEM mentoring in existing programs, and ample opportunity to expand the focus of existing programs or create new programs tailored to the STEM HE mentoring needs.

Also on a more advanced level, the broker system could eventually serve to connect additional groups, beyond HE and PreK-12, which could benefit from more enhanced relationships. These potential connections include those between STEM faculty and education faculty, two-year and four-year institutions, high schools and colleges, industry and HE, Massachusetts' STEM networks, and between different disciplines within a given institution. The broker system could also serve as a resource for undergraduates seeking research opportunities.

INCREASING PREK-12 STUDENT ACHIEVEMENTS IN STEM

In 1993, Massachusetts' state legislature passed the Education Reform Act, which 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. The outcome has been some notable successes such as the improved state curriculum standards, which are rated the very best in the nation. 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.

Unfortunately, not all students fare equally 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. 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. As discussed by the prior working group, it is clear that many students do not make explicit connections between their achievement in science courses and their career possibilities, nor do they understand the range of career options available to them, often confining their vision to what they have been directly exposed to, namely, academic science on the one hand and medicine on the other. We need to deliver the message that solid performance in a STEM major can lead to a lifetime of intellectually satisfying work in industries such as pharmaceuticals, engineering, health care, computer technology and more.

Scientists labor on the edge of the unknown. Whether in academic or industrial laboratories, the everyday practice of science involves narrowing problems down, devising hypotheses, and coming up with unique, viable, and replicable methods for testing these hypotheses. Attendees at the meeting agreed that all students would benefit from following this same process of inquiry- and project-based learning in their coursework, while simultaneously ensuring curriculum coverage for MCAS. Many PreK-12 educators are already working hard to implement these goals. Participants in this working group addressed how HE STEM faculty specifically can help PreK-12 teachers bring these goals to fruition.

Educators at the meeting reiterated the established notion that this type of learning should emphasize teamwork, with students working in collaboration with their peers. The learning should integrate insights from several disciplines at once. It should give students a sense of ownership over a particular project that they can pursue and develop over time. It should give a back seat to memorization and rote learning, and it should allow students to apply scientific principles to real-world challenges. Educators should have the resources required to pursue these goals and they should also be provided a means of assessing the impact of such education efforts that go beyond the MCAS scores. These ideas are not new; rather, they represent ongoing goals in which exists many opportunities for HE STEM faculty to participate.

Science fairs offer one well-established venue for inquiry- and project-based learning. Several participants noted that a replicable framework for engaging more students from lower socio-economic school districts in science fairs is required in the Commonwealth. Some educators also commented that multi-year science fair projects offer advantages, because students commit to a project and work to improve it over several years.

- **RECOMMENDATION.** Create a replicable framework for bringing research experiences to PreK-12 students in lower socio-economic school districts.

- **RECOMMENDATION.** Increase participation of all PreK-12 students in science fairs.

- **RECOMMENDATION.** Urge PreK-12 students and their teachers to consider multi-year STEM research projects to permit students to take full ownership of the projects, to experience improvements in their abilities, and increase the depth of their research experiences.

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. HE faculty might help put the spotlight back on STEM by advocating for the critical need for STEM education.

- **RECOMMENDATION**. HE faculty should identify mechanisms that would enhance their involvement and influence, both at the local and state levels, in community policy discussions dealing with STEM 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 a more formalized mechanism to promote the equipment and technology donations by Colleges and Universities. Several faculty noted that their efforts to provide excess or used equipment were often hindered by University rules regarding equipment donations.

- **RECOMMENDATION**. Create a more formalized mechanism to promote higher levels of equipment and technology donations by colleges and universities to PreK-12 STEM classrooms.

INCREASING THE NUMBER OF STUDENTS WHO GRADUATE FROM A POST-SECONDARY INSTITUTION WITH A DEGREE IN STEM

College students do not always connect the dots between their current coursework and their future career opportunities. Part of the problem comes from lack of awareness about the diversity of career choices available to STEM majors; many students see academia and medicine as the only two options available. We need to broaden their perspectives so that students get exposure to a wider range of scientific careers in industry. Scientists in higher education can take immediate action on this issue by informing themselves about the scientific industries in Massachusetts and the types of careers they offer, and proactively passing this information on to their undergraduate students. Another possibility is to task the STEM industry with ensuring that the needs of the STEM workforce and the diversity

of those professions are communicated directly to the STEM professors and students. One simple solution could be an annual message to the HE faculty and their students to inform them about who represents the STEM industry in Massachusetts, which areas are growing, and what types of positions are in demand. Numerous mechanisms come to mind, including an industry-sponsored seminar series targeting students, STEM profession clubs, and STEM profession honors and awards for graduating seniors.

One of the best ways to expose students to STEM careers is to place them directly into a work environment. Both academia and industry need to increase the number of STEM internships and co-ops that are available in Massachusetts, and help ensure high-quality internship experiences. We also need to reach out and advertise such internships to all interested students, particularly those who don't typically hear about such opportunities. Robust high school and college career guidance programs can play a role in this. Peers can also play a role by helping to recruit their friends into internships. One highly successful route to encouraging undergraduates to pursue STEM careers is the Internship Challenge developed by the Massachusetts Life Sciences Center, which is a workforce development program focused on enhancing the talent pipeline for Massachusetts companies engaged in life sciences.

Realizing that undergraduates require inquiry-based instruction in STEM fields and translating that realization into a solution have proven elusive. Laboratory courses are expensive to create and run; students are usually limited in the number of laboratory courses they can take. Further, HE faculty receives little financial or administrative support for creating meaningful laboratory experiences for their students. Creating incentives for faculty to provide laboratory experiences in their courses, or in their own laboratories, might help improve the situation. A pool of supply funds, additional administrative support and recognition in the promotion process are three potential avenues of encouragement.

Most existing programs that supply in-depth research experiences do so for only a small fraction of the interested students. This approach results in an elitist culture, promoting the idea that very few students are "good enough" to merit the attention or the resources required to do real science. There must be a solution that provides access to research experiences to a wider set of students.

- **RECOMMENDATION**. Create more opportunities for inquiry-based, project-based, and laboratory-based learning for the entire STEM PreK-16 student population.

Another part of the problem in retaining students in STEM majors comes from the obstacles STEM HE faculty inadvertently place in their way. The obstacles vary, and so do the proposed solutions. Large gateway courses at college discourage many students from pursing STEM majors. These courses often seem designed to weed out the weak, rather than invite all students into a major. Higher education faculty could take immediate action on this issue by engaging in frank discussions about the purpose of gateway courses. Faculty can also encourage students to take advantage of proven programs, such as Supplemental Support Instruction. Finally, HE faculty can help students make explicit connections between the preparations provided by gateway courses and STEM careers. If

students can envision the trajectory linking Biology 101 or Chemistry 101 to a satisfying career, they will overcome momentary frustrations and remain committed to the field.

- **RECOMMENDATION.** Higher Education faculty should engage in frank discussions meant to identify and remove the obstacles many students face in pursuing STEM majors.

Many students are interested in STEM, but lack the foundation courses necessary to succeed at the undergraduate level. Some come directly from high schools, while others come from community colleges. These students are at risk for dropping out of STEM fields because they cannot envision a clear trajectory into more advanced STEM courses. Higher education faculty (and undergraduate advisors, in particular) could take immediate action by explaining which foundation courses students need to take *early* in their college careers in order to progress to more advanced STEM studies. Several of the HE faculty present noted the limited levels of faculty advising that occur for students in many STEM majors.

Many students in the Commonwealth start their HE STEM studies at community colleges. Those who choose to transfer to four-year programs are often stymied in their efforts. The reasons are varied, but one key factor is that their credits might not transfer, requiring them to repeat basic courses; or the credits may transfer but not be applied to required STEM courses. Students often end up frustrated and discouraged by the simple process of changing schools. As part of the longer-term goals, attendees at the meeting expressed a desire for a more comprehensive, effective partnership between community colleges and four-year institutions. The goal should be very smooth transfer paths in the STEM fields. Reaching this goal may help to address the problem of high school students who have a high degree of interest in STEM, but may not have had the foundation courses and/or learning necessary to be successful at the Bachelor's degree level.

- **RECOMMENDATION.** Create a more structured relationship between those who work in community colleges and those who work in universities to ensure students can more seamlessly move between higher education options.

The students themselves are the most important stakeholders in STEM education in Massachusetts. So it's important to ask them directly what motivates them to study STEM topics -- and what drives them away. Surveys administered to students before and after graduation could measure rates of employment as well as intellectual satisfaction. Undergraduate students are often the best ambassadors for STEM in the PreK-12 environment. A leadership program could be developed to harness their enthusiasm and energy about STEM subjects and bring that directly into the PreK-12 classroom setting. These activities would provide reciprocal benefits, as the students encourage each other. The PreK-12 students can identify with these near-peer mentors and learn that it is possible to be a scientist and that scientists have access to all kinds of career options. The undergraduate students gain confidence in their knowledge and abilities as they see their mentees engage.

- **RECOMMENDATION.** Engage in a statewide survey of undergraduate students to assess the reasons why they do or do not choose to study STEM topics.

- **RECOMMENDATION.** Create a leadership program to bring undergraduate STEM majors into the PreK-12 classroom.

INCREASING THE NUMBER OF PREK-16 STEM CLASSES LED BY EFFECTIVE EDUCATORS

One of the starting points for this discussion was an acknowledgement of the numerous and varied professional development resources available to Commonwealth STEM 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. Despite such a varied and rich source of professional development resources, many science teachers in the Commonwealth report that they find it hard to find the right resources to meet their needs. They are challenged to find or create the time required to participate in professional development, and find it hard to incorporate what they learn in their PD activities into the already demanding curriculum requirements of their classes and the limited time they are able to devote to science.

STEM fields change rapidly. Pedagogy does too: with inquiry- and project-based curricula, many teachers are being asked to teach in new ways – ways that may be unfamiliar to them. In order to provide the types of STEM learning experiences that we all want for children in Massachusetts, we need a sustained and unified effort to support our classroom teachers. Opportunities for professional development can take several forms. At the simplest level, teachers need increased preparation time for their daily lessons. At more advanced levels, teachers need opportunities for externships, workshops, online courses, summer institutes, and/or sabbaticals which will enable them to stay current in STEM fields as well as in pedagogical methods for science instruction.

Higher education can play a direct role in addressing this challenge by creating more professional development opportunities that directly address the needs of STEM teachers in Massachusetts. Currently, there is limited exchange between faculty in Schools of Education (whose passion is creating PD materials), those in research laboratories (whose passion is engaging in science research), and the PreK-12 teachers (whose passion is teaching). However, the landscape is changing. The National Science Foundation now requires that every grant application include a well-articulated proposal for communicating research results to the public. Administrators in Massachusetts could seize this opportunity to simultaneously raise the research profiles of their universities while creating incentives for faculty to conduct outreach. Specifically, administrators could establish outreach programs that any faculty member could tap into directly, depending upon his or her interests and needs. When those faculty submit grant applications to NSF, their concrete outreach proposals would give them a competitive advantage, eventually resulting in more external funding for the university while also encouraging more scientists to engage with the public. An example of an existing initiative is the Office of Research & Engagement at UMass Amherst's Broader Impacts web page, which was

created to help faculty easily identify, design, and implement the "broader impact" components of their federal research proposals.

- **RECOMMENDATION**. Create programs at universities that will support HE faculty in meeting their federal funding requirements to engage in outreach.

It is important to quantify the effectiveness of such programs in order to assure funding for them. It's also important to provide professional development experiences to all teachers, not just newly recruited ones; doing so could assist with teacher retention. Some attendees mentioned the National Science Foundation, which has programs to provide research experiences to PreK-12 teachers and students. These have demonstrated long-lasting effects. Schools in Massachusetts could potentially apply to NSF for such programs, or build their own programs using these models.

Some attendees also suggested developing a new teacher education program, which would involve superintendents, teachers, presidents of higher education, and non-profits. Businesses should also participate in order to show a sense of urgency and to demonstrate the availability of STEM jobs. All of these STEM stakeholders could be involved in designing undergraduate and professional degree programs for the next generation of teachers. The Department of Education offers grants to facilitate such planning.

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 and exposure to real research experiences can make science more appealing and less intimidating to pre-service teachers.

- **RECOMMENDATION**. HE institutions should create opportunities for pre-service teachers to meet inspiring STEM role models, to gain research experience, and to visit effective PreK-12 STEM classroom settings.

CONCLUSIONS

The Massachusetts Academy of Sciences and the Massachusetts Department of Higher Education were pleased to support this first in a series of events to address the critical role of HE STEM faculty in addressing PreK-12 STEM education reform in Massachusetts. The combination of informal conversations and formal sessions resulted in exciting and productive engagement among the diverse attendees, which included HE STEM faculty, PreK-12 teachers, industrial scientists, non-profit organizations and government representatives. Even more importantly, a comprehensive list of action items was articulated, providing specific focal points for subsequent discussions by HE faculty and administrators.

Many meeting attendees expressed a desire to start work on the problem as soon as possible, by drawing on the existing base of research knowledge. Doing so could give stakeholders an immediate sense of satisfaction, and create synergy and momentum that would help them to tackle some of the larger, longer-term problems facing STEM

education in Massachusetts. In response, the sponsors of this meeting (MAS and MDHE) have proposed a series of follow-up efforts. The first such event will take place at the Massachusetts 2011 STEM Summit, which will be held on October 18, 2011 at the Boston Marriott in Newton, Massachusetts. A special session on the role of HE faculty in STEM education reform has already been organized, and this document will serve as the focus of conversation.

Although some work can and will begin immediately, increasing the number of STEM majors and broadening the base of scientifically engaged citizens will require sustained discussion and effort. The meeting participants articulated a desire for many programs, changes, and incentives that are entirely feasible but will take some time to accomplish. The MAS and MDHE are committed to ensuring that the necessary discussions occur and that the results of these conversations are widely disseminated. Please visit the Massachusetts Academy of Sciences' website to join this conversation and/or to stay informed of the resulting activities.