science technology engineering mathematics

Investing in STEM to Secure Maryland's Future

Final Report of the Governor's STEM Task Force

Presented to Governor Martin O'Malley

August 2009

"Preparing our children for the knowledge-based economy is among our highest priorities as we seek to improve STEM training throughout the state. Even in difficult economic times, we will continue to protect the investments in education at every level, from Pre-K to college, while increasing the alignment between the needs of our partners in the business community and the curricula designed by our educators. This synergy illustrates the emerging reality that just as our challenges are interrelated, so too are our opportunities for the future."

— Governor Martin O'Malley —

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Executive Summary

"Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been."

— Barack Obama, April 2009 —

The problem in Maryland is that although we now have enviable prosperity and a strong knowledge-based economy, competing states significantly out-produce us in terms of science, technology, engineering, and mathematics (STEM) graduates, STEM workforce development, and STEM-based economic development. If present trends continue, our competitors will overtake us. For Maryland, standing still is falling behind.

Maryland Governor Martin O'Malley recognizes the urgency of the current climate of competitiveness and charged a Task Force with making recommendations aimed at establishing Maryland as a global leader in the development of its workforce of the future and its STEM-based research and economic development infrastructure. This report is a response to the Governor's charge. It is a call to action, urging Maryland to adopt a set of initiatives, with international benchmarking, to ensure that the state is globally, not just nationally, competitive. The report calls for higher performance standards in teaching and learning and greater productivity in transforming the state's high volume of research and development (R&D) activity into economic growth and job creation. Specifically, this report sets higher expectations for teaching and learning at all levels of the education spectrum; the expansion of the degree-seeking and degree-completing pipeline in STEM-related fields, including STEM teaching; the development of strategies to link education, workforce creation, research, and economic development; and the creation of measurable goals, benchmarks, and resources to implement this plan.

To carry out its charge, the Task Force divided into three workgroups: STEM education, STEM workforce development, and translational research and economic development. Each workgroup studied and developed recommendations in its assigned area. The Task Force then came together, reaching broad consensus on the most essential steps Maryland must take, grounding its recommendations in evidence-based research reports and analysis of state data. The Task Force is pleased to offer the following seven recommendations:

1. **Align P-12 STEM curriculum with college requirements and workplace expectations in order to prepare ALL students for postsecondary success.**
2. **Triple the number of teachers in STEM shortage areas who are prepared in Maryland programs, increase their five-year retention rate from an estimated 50% to 75%, and enhance the STEM preparation and aptitudes for elementary and early childhood teachers.**
3. **Ensure that all P-20 mathematics and science teachers have the knowledge and skills to help all students successfully complete the college- and career-ready curriculum.**
4. **Provide STEM internships, co-ops, or lab experiences for all interested high school and college students to jump-start their successful transition to the workplace.**
5. **Increase the number of STEM college graduates by 40% from the present level of 4,400 graduates by 2015.**
6. **Boost Maryland's global competitiveness by supporting research and entrepreneurship.**
7. **Create Maryland's STEM Innovation Network to make STEM resources available to all.**

Introduction

In his address to the National Academy of Sciences in April 2009, President Obama made this declaration: "Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been." He went on to announce his $5 billion "Race to the Top" challenge: "I am challenging states to dramatically improve achievement in math and science by raising standards, modernizing science labs, upgrading curriculum, and forging partnerships to improve the use of science and technology in our classrooms. And I am challenging states to enhance teacher preparation and training, and to attract new and qualified math and science teachers to better engage students and reinvigorate these subjects in our schools."[1]

In a global economy, America's competitive edge depends in large measure on how well our schools prepare tomorrow's workforce. Ever since the publication of Tom Friedman's "the world is flat" analysis, the American public has looked to educators and public policymakers to steer a course that will preserve our competitive edge in the global marketplace, and more recently to undertake this task while addressing the pressing challenge of sustainability in a world that is increasingly "hot, flat and crowded." [2] With the publication of *Rising Above the Gathering Storm* in 2007, a report developed by a National Academies committee, chaired by former Lockheed Martin CEO Norman Augustine, both the nation and the individual states were provided a blueprint to guide the development of educational standards, workforce needs, and investments in innovation that would equip graduates and researchers to imagine, invent, and grow our knowledge-based economy.[3]

According to a recent op-ed by Norman Augustine, "The United States ranks 16th and 20th among nations in college and high-school graduation rates, respectively; 60th in the proportion of college graduates receiving natural science and engineering degrees; and 23rd in the fraction of GDP devoted to publicly funded non-defense research. The number of U.S. citizens receiving Ph.D.s in engineering and the physical sciences has dropped by 22% in a decade. U.S. high-school students rank near the bottom in math and science."[4] The National Governors Association has emphasized the importance of STEM because "the global economy has flattened the world in terms of skills and technology. A new workforce of problem-solvers, innovators, and inventors who are self-reliant and able to think logically is one of the critical foundations that drive a state economy's innovation capacity."[5]

Maryland Context

The problem in Maryland is that, although we now have enviable prosperity and a strong STEM-based economy, competing states substantially out-produce us in terms of STEM graduates, in STEM workforce development, and in translating STEM-based R&D into economic growth and job creation. If present trends continue, these states will overtake us. For Maryland, standing still is falling behind.

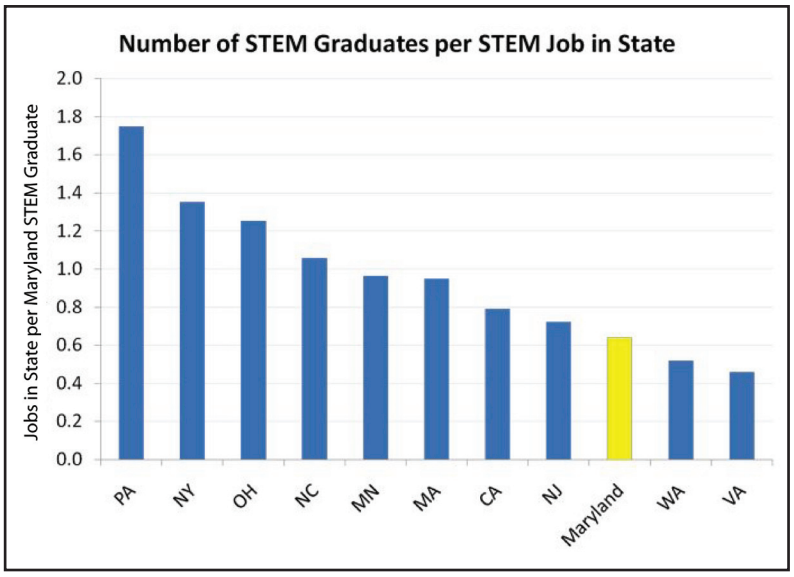
Critical to sustaining and enhancing Maryland's status as a leader in the knowledge-based economy is the strength of the state's STEM educational and research programs; its ability to produce a high quality workforce in STEM areas, both for the P-12 classrooms and the growing STEM-based public and private sectors; and the capacity of its infrastructure to transfer the state's high level and high volume of STEM-based research into economic growth and job creation. Maryland's economy is dependent on a workforce with strong technology skills that foster new connectivity. We hold the belief that access to technology is central to learning experiences for all and needs to be ubiquitous throughout the state.

In a global economy that rewards innovation, creativity, and the education level of the workforce, Maryland's citizens enjoy an impressive level of prosperity, having the nation's fifth highest average income according to the U. S. Department of Commerce.[6] Yet this level of prosperity cannot be sustained without a steady and reliable flow of skilled and talented graduates into the workforce and a vibrant R&D environment that drives economic growth and job creation.

With regard to its future in a technology driven highly competitive economy, Maryland stands at a crossroads. It enjoys considerable strength, which built upon could position the state as a global leader. However, there are also alarming warning signals, which unattended could lead Maryland to become a follower and not a leader. In this sense, for Maryland, it is "the best of times and the worst of times."

For example, Maryland is home to an enormous research enterprise. It has a wealth of high quality and high volume federal research laboratories, including NIH, NIST, NASA Goddard, FDA, NOAA, and Fort Detrick. Maryland also has several major research universities, including The Johns Hopkins University, which is the nation's leading university in the volume of research, as well as the University of Maryland, College Park; University of Maryland, Baltimore; and University of Maryland, Baltimore County, which combined do close to $1 billion of funded research annually. As a result of these impressive research assets, Maryland ranks number one nationwide in R&D per capita and third behind only California and Massachusetts in the total volume of research.[7] In part because of this huge volume of R&D, the Milken Institute's most recent rankings place Maryland second nationwide for technology economy preparedness.[8] However, Maryland does not fare well in competition with other states in terms of its ability to move research discoveries to the marketplace. As a result, Maryland significantly underperforms in terms of creating new companies, jobs, and economic growth emerging from its research and development prowess.[9]

Maryland ranks second in the nation in professional and technical workers as a percentage of the workforce and has over 220,000 workers employed in professional, scientific, and technical service industries.[10] The state's STEM-related industries account for millions of dollars in economic investment. But, with an aging workforce, significant shortfall in qualified K-12 STEM teachers, and a rapidly changing economic and social environment, Maryland cannot assume that it can maintain this advantage unless and until it attends to the emerging challenges facing the state in STEM education and workforce development. Indeed, while national assessments of education quality, education level of workforce, and R&D volume place Maryland among the nation's leaders, Maryland already suffers from a shortage of highly qualified STEM workforce. We have approximately 6,000 STEM openings a year and we produce approximately 4,000 STEM graduates, one of the largest STEM workforce deficits among Maryland's competitor states.[11]



Source: IPEDS and America's Career Infonet

According to *Education Week,* Maryland leads the nation in efforts to align P-12 standards with early learning and college and career expectations[12], and *Newsweek* has recognized Maryland for the nation's highest Advanced Placement (AP) participation.[13] Maryland's achievements in P-12 education are the result of the extended education community's efforts to establish policies and grow programs that move all of the state's P-12 students into a successful postsecondary experience either in college or the workforce. Yet, despite these enviable accolades, according to the most recent international benchmarking studies of mathematics achievement, Maryland's K-12 competitiveness is ranked no higher than C+.[14]

Fortunately, there is considerable interest among Maryland policymakers for building strong capacity in STEM areas, including education and research. For example, Maryland joined 49 states and territories in the Common Core State Standards Initiative, a states-led, national effort to develop common P-12 standards in English and mathematics that are research-based, aligned with college and work expectations, and internationally benchmarked. This effort is a logical next step that builds on work Maryland has done over the last decade. As part of the national reform effort, Governor O'Malley has called for a longitudinal data tracking system that will follow students throughout elementary, middle, and high school and into college and beyond.

In December 2008, the Commission to Develop the Maryland Model for Funding Higher Education (Bohanan Commission) focused on the college readiness of students in the STEM fields because STEM is an essential element in addressing Maryland's competitiveness and workforce needs.

The Bohanan Commission also recognized the important foundation of primary and secondary education in preparing students for college, so the commission examined education efforts from preschool through graduate school (P-20). The P-20 reference emphasizes that a state's system of education encompasses preschool through graduate studies and that learning at all levels must prepare students for education at the next higher level and for success in a competitive workplace.

In recognition of the importance of collaboration in P-20 education, Governor O'Malley initiated the P-20 Leadership Council of Maryland in October 2007 to investigate ways to improve education, advance workforce creation, and make the state more competitive in securing and maintaining business and economic development.

Taken together, this is an impressive level of commitment by Maryland's policymakers to address Maryland's challenges and to move Maryland on a path to global leadership in STEM education and economic growth. These policy decisions have established critical momentum for the work of the STEM Task Force.

While Maryland faces many challenges in securing its place among the world's most successful and dynamic economies, clearly its assets outweigh its liabilities. Given the presence of a disproportionate number of major federal labs, strong systems of P-12 and postsecondary education, research universities that rank among the world's best, and the commitment of the state's most important leaders, Maryland has the potential to advance and sustain its leadership in the knowledge-based global economy. With planning and strategic investments, Maryland can build on its impressive strengths and create a high performing economy; meaningful, challenging jobs for its workforce; and an enviable quality of life for its citizens.

Charge to the Task Force

Recognizing both the opportunities and challenges facing Maryland, Governor O'Malley in September 2008 created a STEM Task Force and charged it with making recommendations aimed at establishing Maryland as a global leader in the development of its workforce of the future and in its STEM-based research and economic development infrastructure. The Task Force was asked to create a statewide STEM action plan that would ensure the quality and quantity of Maryland's workforce of the future and a globally competitive research and development infrastructure that would position Maryland as a leading knowledge-based economy. Specifically, the Task Force was charged to develop an action plan to:

- Ensure that rigorous STEM teaching and learning are accessible to all learners and at all levels of education;
- Increase the number of degree holders and program completers trained in STEM fields;
- Include strategies to synergistically link education, workforce creation, research, and economic development; and
- Include measurable goals, benchmarks, and the resources required to implement the plan.

The co-chairs of the Task Force—William E. Kirwan, Chancellor of the University System of Maryland, and June Streckfus, Executive Director of the Maryland Business Roundtable for Education—defined an overarching goal for the Task Force's work:

> *Maryland will be a national leader and globally competitive in STEM education, pre-K through 20, in STEM workforce development, and in STEM-based economic growth and job creation.*

Work of the Task Force

To carry out the Task Force's work, the co-chairs appointed and charged three workgroups aligned with the three components of the charge. These three workgroups and co-chairs were as follows:

P-12/Higher Education Alignment and Teacher Production Workgroup

Michael Martirano,
St. Mary's County Public Schools

Dennis Pataniczek, Salisbury University

STEM Workforce Workgroup

Eugene DeLoatch, Morgan State University

Rizwan Siddiqi, EBA Engineering Inc.

Translational Research and Economic Development Workgroup

Stephanie Hill, Lockheed Martin

Nariman Farvardin, University of Maryland, College Park

Within their areas of study, the workgroups were asked to develop reports that accomplish the following:

- Provide an analysis of the state's strengths and weaknesses;
- Provide three major recommendations that would enable the state to achieve the relevant portion of the Task Force's overarching goal; and
- Develop benchmarks that can be used to measure progress toward the Task Force's overarching goal.

The Governor's STEM Task Force draws its final recommendations from the workgroup recommendations. In arriving at these recommendations, the Task Force and the workgroups benefited from previous analyses of both the strengths and the weaknesses in the three target STEM areas: education, workforce, and translational research and technology transfer. The STEM Task Force and workgroup research included a review of statewide reports and recommendations from prior committees and task forces including those charged by the Maryland State Department of Education (MSDE), the Governor's Workforce Investment Board (GWIB), the University System of Maryland (USM), the P-16 Leadership Councils (2000-2007), as well as a review of recent national reports coming from the National Academies, National Governors Association, the Business-Higher Education Forum, and Achieve Inc., among others.

In addition, the committee studied comparable states, as identified in the Bohanan Commission report, and participated in actual and virtual site visits to Ohio and North Carolina to learn about promising model programs. Workgroup members met in person, shared information, and submitted recommendations electronically. The workgroup co-chairs met regularly throughout the past six months with the Task Force co-chairs and with the consultant to the Task Force in the preparation of these recommendations.

The recommendations that follow are organized according to a logical progression moving from schools, to workplace, to research that promotes economic growth and job creation. Each of the seven recommendations is stated as an overriding goal followed by a narrative reviewing the strengths and weaknesses of the Maryland context, and citing evidence-based research to support "best practice" recommendations. Each recommendation is followed by a set of benchmarks and actions that include timeframes. A budget impact analysis is presented at the end of the document.

THE RECOMMENDATIONS

Recommendation 1:

Align P-12 STEM curricula with college requirements and workplace expectations in order to prepare ALL students for postsecondary success.

According to *Achieve Inc.,*

> "In the last decade, research . . . has shown a strong convergence in the expectations of employers and colleges in terms of the knowledge and skills high school grads need to be successful, especially in English and mathematics. Economic reality reflects these converging expectations. The bottom line is that today all high school graduates need to be prepared for some postsecondary education and/or training if they are to have options and opportunities in the job market. As such, our education system should be preparing students for entry into middle- and high-skilled jobs, which offer a higher wage and represent a broader set of opportunities in the workforce, rather than low-skilled jobs that pay less, have fewer benefits, and now account for only one-fifth of all jobs. Being 'college and career ready' ultimately means that students are prepared for their next steps, that all doors remain open to them as they continue to pursue their education and their careers."[15]

In Maryland, the Bohanan Commission forcefully supported the adoption of a statewide P-12 curriculum that is aligned with global workforce and academic standards. "The curriculum should have a strong emphasis on STEM; should provide a seamless transfer into postsecondary education; and should include a definition of standards for teaching, writing, mathematics, and science." In addition the Commission called upon the state to "develop a common definition and measurement of college readiness so that regardless of which school or college they attend in the state, students are aware of, and encouraged to take, the courses they need at the secondary level to be prepared for college level work."[16]

Maryland's leadership in the implementation of innovative programs to prepare students better, especially minority students and under-served populations, for college and the workplace has been recognized with a first-in-the-nation ranking by *Education Week.*[17]

Approximately one-third of Maryland high school graduates in 2008 completed the minimal math and science coursework that will allow them to enroll in college level STEM courses. In partnership with the Governor and the State Superintendent of Schools, the Maryland Business Roundtable for Education is leading a statewide effort—Maryland Scholars—to raise the percentage to two-thirds by 2011.[18]

The Maryland State Department of Education is funding the development and implementation of high school curriculum designed to prepare students for careers in the engineering, biomedical science, and environmental science fields. And, Maryland has topped the nation in the number of students enrolled and succeeding in Advanced Placement courses.[19]

Yet, many Maryland students are being shut out of futures that hold the promise of economic stability and intellectual satisfaction because of poor preparation for life beyond secondary school. Of those entering high school,

about one quarter will fail to graduate.[20] According to the 2009 Student Outcome and Achievement Report (SOAR) prepared by the Maryland Higher Education Commission, of those Maryland students who graduated from a college-prep program in 2006 and entered a Maryland public college, over 30% required college remediation; the rate jumped to near 50% for all other graduates.[21] That same report noted that there is no guarantee that all students who took a particular course were adequately prepared to be successful in a college or university setting; the content and level of rigor of high school courses vary across counties, schools, and even within the same school.

To overcome shortfalls in the preparation of Maryland students for successful transition to postsecondary education, the Governor's P-20 Leadership Council established the College Success Task Force to examine current P-12 and higher education policies and practices related to alignment of educational standards, expectations, and student learning outcomes. The College Success Task Force will recommend policy revisions and/or new practices to raise standards and ensure that high school graduation requirements are aligned with entrance expectations for postsecondary education, which for USM institutions now include three years of science and three years of mathematics capped with a minimum of Algebra II.[22] The Governor's STEM Task Force recommends that high school course requirements include four years of challenging mathematics in high school at least through Algebra II.

Since research has shown that middle- and high-skill jobs now require the same knowledge and skill sets as those required for entrance into a postsecondary college education[23,24], the STEM Task Force is committed to ensuring that all Maryland high school students—those enrolling in two- and four-year institutions, as well as those students entering industry/occupational certification programs, apprenticeships, the armed forces, and middle-skill jobs—graduate prepared with these skill sets.

In addition, the STEM Task Force recognizes the need for interdisciplinary knowledge and skills required for success in higher education and the workplace. Defining a high-quality default P-12 curriculum will require more than designating a set of courses from among existing offerings. The required curriculum must be aligned from elementary school through middle and high school; it also must prepare students to successfully function in academic and workplace environments that require them to integrate ideas from across disciplines in order to solve complex and unscripted problems. The STEM Task Force supports the adoption of a P-12 required curriculum that exposes students to project-based, cross-disciplinary experiences that reflect the changes in the 21st-century workplace. Maryland's participation in the national Common Core State Standards initiative will provide guidance to Maryland as it seeks to develop and implement a P-12 mathematics curriculum that is research-based, aligned with college and workplace expectations, and internationally benchmarked.

Finally, none of these goals will be accomplished if the students cannot see themselves as fully engaged participants, ready and able to enter the world of work empowered with knowledge, skills, and aspirations. The STEM Task Force reached out to the science industry community in Maryland, and solicited a plan for ensuring that all young people are made aware of STEM career opportunities and are well prepared to develop the skills needed to pursue them. Establishing a consistent, high impact, and memorable STEM message will help to centralize activities and generate support for sponsorships, local advertising, and relations with industry partners.[25]

Underlying the discussions and recommendations of this report are two core beliefs. First, Maryland must commit to an education system that sets high expectations for all of its students. The keystone effort to create the

competitive workforce of the 21st century, from the middle-skills jobs to the Ph.D. scientists and engineers, is the preparation students receive in elementary, middle, and high school. This preparation will ensure that those students seeking a two- or four-year degree will successfully transition to college and that those students who wish to immediately enter the workforce will be qualified to do so and will be equally qualified to pursue any level of higher education they desire. Second, this commitment must be coupled with a pledge to secure the resources and support necessary to ensure that all students meet the high expectations and requirements set for them.

Recommendation 1: Actions, Benchmarks, and Timelines

Align high school graduation requirements with USM admission standards and workforce expectations (2011), with the goals of:

- ✔ Increasing the percentage of students graduating from Maryland high school with a college- and career-ready diploma from 35-40% to 80%. (2015)
- ✔ Increasing the percentage of high school students taking Advanced Placement Mathematics examinations from 15% to 20% and taking Advanced Placement Science examinations from 14% to 20%. (2015)
- ✔ Increasing the percentage of Maryland high school graduates enrolling in Maryland's two- and four-year colleges or career education programs from 65% to 85%. (2015)
- ✔ Reducing the percentage of Maryland high school graduates enrolled in remedial courses in Maryland's institutions of higher education by 50% (from 42% of students to 21% of students). (2015)
- ✔ Increasing the percentage of Maryland high school graduates who earn an associate degree at a Maryland community college or who transfer to a four-year Maryland institution of higher education within four years of graduating from high school from 47% to 60%. (2018)
- ✔ Increasing the percentage of Maryland high school students who graduate with a baccalaureate degree from a Maryland institution of higher education within six years of graduating from high school from 67% to 85%. (2020)

Create a statewide marketing campaign to increase STEM interest and promote action.

- ✔ Develop a toolkit to provide multiple means of disseminating the STEM message to various constituents.

Recommendation 2:

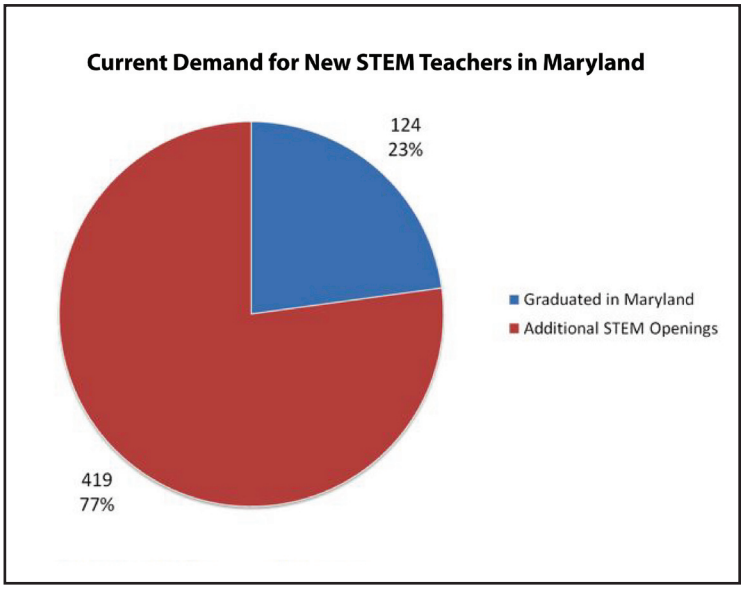
Triple the number of teachers in STEM shortage areas who are prepared in Maryland programs, increase their five-year retention rate from the present estimated rate of 50% to 75%, and enhance the STEM preparation and aptitudes for elementary and early childhood teachers.

Increasing the number of students prepared for successful entry into higher education or the workplace will not happen unless the U.S.—and Maryland—addresses the problem of developing and sustaining a highly qualified mathematics and science teacher workforce. The Business-Higher Education Forum (BHEF)—a national organi-

zation of CEOs, higher education leaders, and foundation leaders—has reported some alarming facts related to mathematics and science teachers:[26]

- The size and composition of the school-aged population are expected to increase by 10% in the next two decades. All of these students will be required to take more—and more advanced—mathematics and science, compounding the existing teacher shortage problem.
- Trend data indicate that the percentage of high school mathematics and science teachers age 50 and older is steadily increasing, leading to high retirement rates.
- Urban and rural schools, often the location of the traditionally underserved, are finding it especially difficult to recruit and retain highly qualified mathematics and science teachers.
- School districts that are importing mathematics and science teacher from overseas find their off-shore supply threatened by the instability in the number of available visas and by an international shortage of mathematics and science teachers.
- Starting salaries for mathematics and science teachers have failed to keep pace with occupations requiring a similar educational background.
- Few U.S. students are drawn to teaching mathematics and science, a profession they see as offering low pay, lock-step advancement, poor working conditions, and public disdain.
- The retention of mathematics and science teachers is an even greater problem than recruitment. According to national data analysis, annual turnover of mathematics teachers (16.4%) is the highest of all content areas; the rate for science teachers (15.6%) is second highest.

The BHEF summarized findings from educational research and investigated programs and practices that were showing progress in easing mathematics and science shortages.[27] The list of promising interventions included: increasing financial and professional incentives, including scholarships, fellowships, signing bonuses, differential pay, tax relief, loan forgiveness, housing subsidies, stipends, and relocation costs; recruiting STEM professionals and retirees into STEM teaching; targeting potential teachers as early as grade 6; instituting college programs to fast-track STEM majors into STEM teaching; implementing comprehensive three-year induction programs; addressing job dissatisfaction, which often results from poor school-based administration support; and combating teacher isolation by promoting teacher learning communities.



Source: USM STEM Workforce Data Book

Recruitment

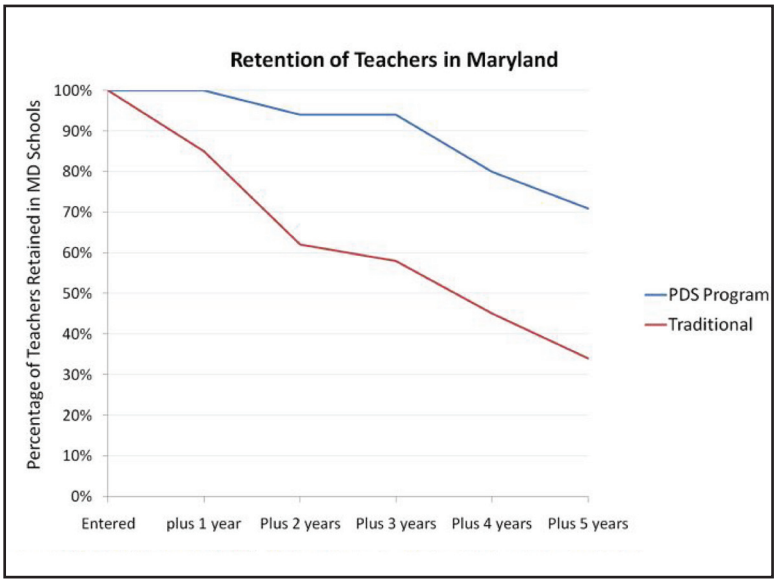
The shortage of teachers in certain STEM fields (Chemistry, Computer Science, Earth/Space Science, Mathematics, Physical Science, Physics, and Technology) is a phenomenon in all 24 Maryland public school systems, with significant implications for urban and rural jurisdictions.[28] At present Maryland depends on other states for the majority of its newly employed teachers.[29] Some Maryland school districts have been forced to recruit qualified teachers from as far away as the Philippines.

Increasing the number of teachers in Maryland's STEM-shortage fields requires a multi-pronged approach that must:

- Expand the capacity of Maryland's teacher preparation programs and Professional Development Schools to produce more certified middle and high school STEM teachers and elementary teachers with greater knowledge of STEM subjects;
- Expand access to Maryland's alternative preparation programs for STEM career-changers and retirees;
- Create new programs for undergraduates to attract Maryland's STEM college students into STEM teaching; and
- Generate interest in STEM teaching careers early on among K-12 students.

Maryland requires that its institutions of higher education prepare its future teachers within the framework of the 1995 *Maryland Redesign of Teacher Education,* which mandates Professional Development Schools (PDSs). PDSs provide students with year-long intensive mentoring and field experiences throughout their training process. Evidence has shown that the PDS program has significantly increased teacher retention rates in Maryland which, according to national and state data, is critical to solving the teacher shortage crisis.[30]

Since PDSs are the primary in-state route to Maryland's teaching profession, Maryland's commitment to preparing ALL students for postsecondary success requires that it expand its production of STEM teachers entering the profession through PDSs. In addition, the requirement to strengthen the STEM background of all students will require not only more middle and high school STEM teachers prepared in PDSs, but a new generation of elementary school teachers who have expertise, appreciation, and understanding of integrated and interdisciplinary STEM concepts. The Maryland Teacher Shortage Task Force and the USM Presidential Task Force on STEM Workforce recommended dedicated and sustained funding for PDSs as part of an updated redesign of teacher preparation.



Source: Proffitt, T.D. (2009, February). A longitudinal study examining the value-added impact of undergraduate and graduate level professional development school preparation on teacher retention. Paper prepared for presentation at the International Conference on Education, Honolulu, HI, January 7, 2009.

Twelve of Maryland's school districts have implemented state-approved alternative preparation programs for STEM retirees and career-changers. Experience in implementing these initiatives suggests program changes for increasing participation: more flexibility in program requirements, alternative delivery models, and increased financial support for teacher-candidates while in training.

Also, the USM Presidential Task Force on STEM Workforce recommended the implementation of a Maryland STEM-Teach program, a variation of the University of Texas' UTeach program that recruits Texas STEM majors into an intensive STEM teacher preparation program. This program includes early identification and recruitment of potential STEM teachers, monetary and tuition enrollment incentives for STEM majors, P-12 clinical experiences throughout the program, scholarships for good performance, and stipends for P-12 and higher education faculty mentors. STEM-Teach would work in collaboration with Maryland's PDSs to provide the meaningful field experiences that have been a key component of success for PDSs.

Retention

The Governor's Workforce Investment Board (GWIB)'s Education Industry Steering Committee declared *"Attract and Retain"* as THE category "that encompasses nearly every critical component of the education workforce crisis."[31] It listed 'Increase financial incentives' as its #1 recommendation to address this crisis, calling for competitive salaries, pay differentials, and financial assistance in the form of loans, grants, and tuition waivers. The Maryland Teacher Shortage Task Force stated that "Improving teacher retention starts with the need for higher salaries and items such as mentoring, induction, and professional development. An improvement in retention, however, represents a return on investment given the high cost of teacher turnover. A recent study estimates that each year Maryland spends more than $42 million on teacher turnover."[32]

States have begun to grapple with the teacher compensation question; two of Maryland's competitor states are experimenting with alternative compensation systems. Minnesota has introduced a voluntary state-level differentiated teacher compensation program, while North Carolina is piloting pay for performance and differentiated pay programs at the district level. **Maryland should consider instituting differentiated pay incentives to recruit STEM teachers into specified school districts and/or specified hard-to-staff schools.**

Non-competitive salary is just one factor that states are addressing in an attempt to reduce teacher attrition. The BHEF offered three other issues that influence teacher retention: lack of induction, job dissatisfaction, and teacher isolation.[33] Comprehensive induction programs, which have shown to reduce the turnover rate of first-year teachers from 41% to 18%, have been funded and implemented statewide in 22 states. Research has shown that induction programs increase five-year retention rates of new teachers from 50% to over 80%. In its 2009 report, the Maryland Teacher Professional Development Advisory Council (PDAC) outlined the characteristics required of a comprehensive induction program. The Council noted that "although some elements of local programs (to support new teachers) are solid, the possible lack of coordination among program components and the uneven availability of program supports for new teachers seriously undermine the overall quality of these efforts."[34]

To address teacher job dissatisfaction, states are experimenting with school-based administrative support that encompasses an array of teacher services: mentoring, professional development, classroom observation and analysis, targeted assistance related to content and pedagogy, training in the effective use of data, and career counseling. Research on international programs points to the value added of administrators tasked specifically with facilitat-

ing meetings to address teacher identified issues of immediate concern.[35] The STEM Task Force recommends that five school districts pilot a STEM Coordinator Program that would place a coordinator at each participating school who would be responsible for implementing high-quality induction for STEM teachers, developing embedded STEM professional development tied to classrooms, and providing targeted assistance to STEM teachers. These coordinators would catalyze the school's STEM community into a community of learners and link to the broader community of STEM educators P-20.

To alleviate the widespread problem of teacher isolation, another leading cause of teacher turnover, states are building communities of learners, both face-to-face and virtual, in which groups of teachers convene to collectively analyze, reflect on, and solve problems of teaching and learning. These communities also engage with experts in government, higher education, or industry, and can offer teachers opportunities to learn from and engage with STEM practitioners and policymakers.

Recommendation 2: Actions, Benchmarks, and Timelines

Triple the number of STEM teachers (currently 150 annually) produced by Maryland programs. (2015)

- ✔ Expand and fully fund Maryland's Professional Development Schools. (2011)
- ✔ Establish Maryland STEM-Teach programs at Maryland colleges and universities to increase the number of STEM majors who earn teacher certification. (2015)
- ✔ Expand alternative certification programs and seek federal funding for the STEM Career Changer Scholarship Program. (2012)
- ✔ Expand Future Educators of America (FEA) clubs across the state. (2011)

Raise Maryland's five-year retention rate for STEM teachers to 75% by 2015 from the present estimated rate of 50%.

- ✔ Implement a comprehensive, statewide teacher induction program for all STEM teachers. (2011)
- ✔ Seek federal funding for pilot programs establishing a school-based administrative program, the STEM Coordinator Program, to work with STEM teachers. (2014)
- ✔ Convene a Governor-appointed panel of education stakeholders, including teachers, to recommend policies on teacher incentives with specific attention to competitive compensation for teachers in STEM-shortage areas and other hard-to-fill positions. (2010)
- ✔ Seek federal funding to expand Maryland's learning communities beyond those established by USM's NSF-supported VIP K-16 program to ensure that all Maryland STEM teachers and higher education faculty have access to a virtual or face-to-face community of learners. (2010)

Recommendation 3:

Ensure that all P-20 mathematics and science teachers have the knowledge and skills to help all students successfully complete the college- and career-ready curriculum.

Research has established that the quality of P-12 mathematics and science teaching is the single most important factor in improving student mathematics and science achievement[36], and the quality of college-level science and mathematics teaching has an influence on the quality of P-12 teaching and the persistence of STEM majors. A number of national reports have called upon all educational stakeholders to support programs and policies that will improve the content-knowledge and pedagogical skills of all P-12 mathematics and science teachers.

- The National Commission on Mathematics and Science Teaching for the 21st Century issued a well-respected report that argued that "the future well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science."[37] That report also argued that "the most powerful instrument for change, and therefore the place to begin, lies at the very core of education—with teaching itself."
- *Rising Above the Gathering Storm* asserted that P-12 student interest and performance in mathematics and science are "solidly linked to teacher excellence."[38] Two of the report's three education actions focused on the preparation of new P-12 teachers of mathematics and science and the professional development of the existing teaching force in these fields in grades 6–12.
- *An American Imperative* summarized the work of educational researchers investigating the characteristics of teacher education and professional development programs that produce successful mathematics and science teachers.[39] According to the research, effective teacher preparation programs are reviewed and revised regularly, require an undergraduate degree in the content area to be taught, emphasize the development of age-appropriate pedagogical skills built on evolving research on how students learn, are aligned with the state's curriculum, and include supervised classroom experience. The research also supports the development of programs to produce elementary mathematics and science specialists and programs for career changes that emphasize pedagogical skills and supervised classroom instruction of students. As stated in the report, effective professional development programs are ones that are focused on "student learning expectations, tied to what is happening in local classrooms, sustained over time, and understood and supported by school administrators."

Over the years, Maryland task forces and workgroups have adopted recommendations to improve teacher preparation and professional development. Some adopted recommendations have been implemented, while others languish. The current mandate to implement a more rigorous P-12 STEM curriculum for all Maryland students requires a review of Maryland's efforts to ensure a highly qualified STEM teaching force and a reconsideration of the recommendations regarding teacher preparation and professional development that have been proposed but remain unimplemented. Significant thought was given to a recommendation by the Maryland Teacher Shortage Task Force to revise the 1995 *Maryland Redesign of Teacher Education.* In justifying the need for this recommendation, the Task Force provided the framework for undertaking the revision:

- Incorporate current research findings on teaching and learning;
- Consider the changing state demographics;
- Reflect the requirements of higher student expectations;
- Recognize the new non-traditional pathways to teaching;
- Consider teaching at-risk children in challenging schools;
- Review the impact of national accreditation on Maryland's preparation and professional development programs;
- Expand higher education's partnership role with K-12 schools during teachers' induction years;
- Develop a research and evaluation component to support revisions in future years; and
- Consider alternate solutions to STEM teacher shortages, including the development of a rigorous interdisciplinary STEM teaching major.[40]

The STEM Task Force recognizes the work of the Maryland Teacher Shortage Task Force and supports its recommendation for a review and update of the *Maryland Redesign of Teacher Education.* The STEM Task Force recommends that those undertaking this revision consider the evolving nature of STEM education from a "siloed" structure to an integrated disciplinary approach and how this change will affect the preparation of P-12 STEM teachers. This will require revising both the content and the pedagogy of STEM coursework.

In addition, the STEM Task Force recommends the development of new programs that are specifically designed to produce specialists in STEM teaching at the elementary level, the expansion of programs (such as an interdisciplinary-STEM certification) to produce the caliber of middle school teachers needed to teach higher-level STEM courses that are being offered in the middle grades, and the establishment of a STEM-teacher internship program—the Maryland STEM Teacher Summer Fellowship Program—modeled on the San Francisco Bay area's Industry Initiatives for Science and Math Education Summer Fellowship Program. This highly successful program is a partnership between a consortium of San Francisco-area companies and the Lawrence Hall of Science, Berkeley. It provides P-16 teachers with paid industry- and research-based professional development opportunities while completing a project for their company sponsor. The teachers develop plans to transfer their experience to their students and colleagues, are provided opportunities to develop inquiry-based lesson plans to be shared over the Web, and are invited to apply for innovation grants to implement creative ideas to enhance instruction.

All aspects of teacher professional development in Maryland have been addressed by the Maryland Teacher Professional Development Advisory Council (PDAC), which sets standards for professional development and created planning and evaluation aids to assist school systems, MSDE, higher education institutions, and other providers in planning, implementing, and evaluating professional development. A 2008 PDAC report identified shortcomings in the state's professional development programs and made several recommendations for improvement.[41] The recommendations included more strategic use of PDAC's planning materials to implement the professional development standards and a call for deploying and supporting school-based professional development staff to provide on-going and school-specific professional development. The STEM Task Force supports PDAC's recommendation for school-based professional development staff.

The 2006 report of the Governor's STEM Education Advisory Committee made a strong case for Regional Professional Development Collaborative Resource Networks to support preK-12 programs across the state.[42] These regional centers would be linked to school districts and higher education institutions to support the transformation of teacher content knowledge and teaching methods, teacher preparation, and instruction in the science, technology, engineering, and mathematics fields. In the report, Maryland industry was encouraged to play a significant role in providing hands-on engineering and science applications for preK-12 classrooms. The STEM Task Force endorses this recommendation, but envisions a broader outreach through the use of a technology supported collaborative resource network to accomplish the same goals.

Recommendation 3: Actions, Benchmarks, and Timelines

Provide every STEM teacher an opportunity for research-based professional development. (2015)

- ✔ Seek federal funding to establish the Maryland STEM Teacher Summer Fellowship Program. (2010)
- ✔ Seek federal funding to establish Regional Professional Development Collaborative Resource Networks. (2010)

Revise and update the Maryland Redesign of Teacher Education. (2012)

- ✔ Establish a Maryland Redesign of Teacher Education Task Force to review and update teacher preparation programs in light of the framework developed by the Maryland Teacher Shortage Task Force. (2010)
- ✔ Develop and implement a math and science specialist endorsement for elementary school teachers and STEM certification for middle school teachers. (2012)

Recommendation 4:

Provide STEM internships, co-ops, or lab experiences for all interested high school and college students to jump-start their successful transition to the workplace.

Whether it is labeled as an internship, co-op, laboratory or research experience, externship, or a service learning experience, a student's step into a professional STEM work environment provides an educational experience unlike anything available within the walls of the "academy." Internships place high school and college students in the heart of some of the most exciting research environments, working side-by-side with some of the leading scientists in the world. Interns are immersed in real-world applications of STEM disciplines and in research projects related to the interests of their mentors.

Most internships offer student participants a wide range of experiences beyond their research activities including scientific coursework, seminars featuring distinguished STEM investigators, informal talks on opportunities for future science-based education and careers, and an opportunity to present the results of their own research to a broad community of STEM professionals. All STEM internships provide work experience that connects the theoretical knowledge gained in the classroom with the practical requirements of daily work in the field. They allow students to "test drive" a career while learning from professionals who have the experience they're looking to gain. For many high school students, an internship is their first foray into the world of work. It provides an

opportunity to develop the skills, attitudes, and habits required to be successful on the job: time management, meeting deadlines, following directions, problem solving, interpersonal communication, leadership, and teamwork. At the same time, an internship allows students to develop greater awareness of their career goal, aptitudes, and interests.

For college students, an internship or co-op experience significantly increases the likelihood of their graduation in a STEM field, assists in initiating the building of a professional network, ensures that their job skills are up-to-date and marketable, and improves their potential for employment. For employers, internships and co-op experiences provide an opportunity to meet and assess prospective employees and to feed information back to higher education and secondary institutions on the competency level of their students and on the current needs of the STEM workplace. Many employers of scientific workers are concerned about the future of STEM in the U.S., and see the sponsorship of internships or co-op experiences as a way to influence the academic choices of students and to attract and retain them into STEM disciplines.

College and high school STEM internships and co-op education programs exist in Maryland and the importance of these experiential learning experiences is broadly accepted. Summer STEM programs for high school and college students, as well as year-round STEM work opportunities, exist in the private sector, on many of Maryland's higher education campuses, and at the large number of federal facilities and laboratories spread across the state. However, the number of STEM internship openings is just a fraction of the total number of Maryland's STEM student population, resulting in a very competitive environment and a lost opportunity to build the interest and excitement of a much larger pool of potential STEM professionals.

While industry and government agencies are anxious to share their high level of subject matter expertise in efforts to improve P-12 STEM education, they are insulated from P-12 and higher education by regulation and organization. Many of their experiential learning programs are organized on an ad hoc basis, or through the personal connection of individual business people, professors, or teachers. There is no comprehensive, systemic effort to assist STEM employers in establishing a program; to recruit STEM employers, especially from the under-represented small and medium business sectors; to develop internship program standards; to place students in meaningful internships; to conduct short- and long-term program evaluations; and to focus on significantly increasing the participation of minorities and women in STEM experiential programs.

Recommendation 4: Actions, Benchmarks, and Timelines

Increase the number of high school students declaring an initial major in STEM from an average of 3,500 to 5,000 per year as reported on MHEC Application Information System. (2014)

- ✔ Develop and distribute information and materials to students promoting STEM education and careers. Use existing student websites and other communication vehicles. (2011)

Increase the percentage of high school graduates who participate in STEM internships, co-ops, or lab experiences or similar STEM experiential learning opportunities during high school from approximately 5% to 20%. (2015)

Increase the percentage of STEM college graduates who participate in STEM internships, co-op programs, or similar STEM experiential learning opportunities during either their college years from approximately 50% to 75%. (2015)

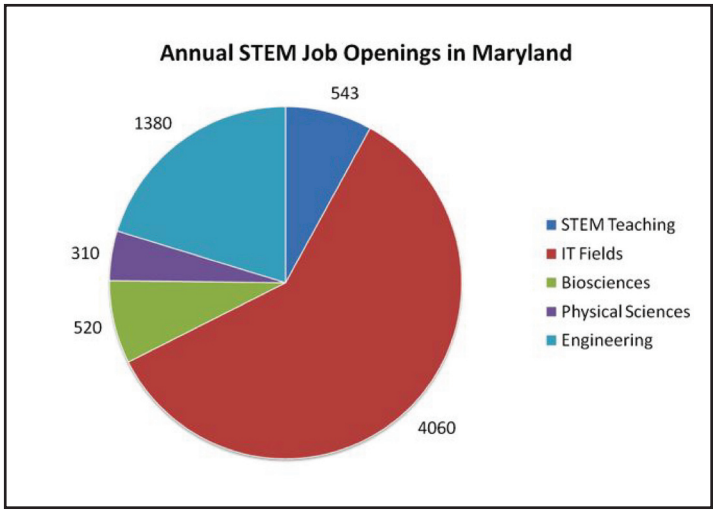
- ✔ Establish a web-based STEM Experiential Learning Program to coordinate the statewide development of college and high school STEM internships, co-op programs, research experiences, externships, and appropriate service learning experiences. (2011)
- ✔ Conduct a survey of employers to determine the level of satisfaction with both the programs and student participants. (2015)
- ✔ Seek federal and private funding for the internship scholarships. (2010)

Recommendation 5:

Increase the number of STEM college graduates (currently 4,400) by 40% by 2015.

Science, technology, engineering, and mathematics—and the innovation they support—are critical to our country's economic growth, global competitiveness, and national security. Leadership in these fields is essential to us as individuals and as a nation. It will take the collective effort of all stakeholders—educational institutions, government, and business—to ensure that the U.S. is able to attract, educate, and retain a STEM workforce prepared for the challenges of the knowledge-based economy.

Maryland has been recognized for a highly educated workforce that is on the cutting edge of scientific breakthroughs and innovation. However, Maryland's production of STEM graduates has not kept pace with the increasing market demand for STEM workers. Just as important, Maryland suffers from a "brain drain;" one out of three Maryland high school graduates who go on to college leaves the state to attend out-of-state colleges and universities.[43] According to some national sources, 70-75% of those highly talented students who leave a state, including Maryland, do not return.[44]



Source: USM STEM Workforce Data Book

The high demand in Maryland is fueled by a strong federal technical and research presence in the state and a large cadre of private STEM contractors who support federal projects and policy initiatives. The arrival of thousands of new high-tech jobs under BRAC, the Base Realignment and Closure process, while solidifying Maryland as a STEM-centric workplace, will further exacerbate Maryland's deficit of STEM workers.

For the approximately 6,000 STEM job openings each year, Maryland's institutions of higher education are graduating about 4,000 STEM graduates.[45] The higher education pipeline begins in the P-12 schools with strong elementary and middle school teachers who have experienced high quality, integrated STEM teacher preparation programs. To build the pipeline will require an investment at every stage of that pipeline.

States that are successfully inducing growth in STEM industries have more STEM graduates per year than STEM job openings. Maryland lags behind its identified competitor states, ranking eighth out of 11 states in the ratio of STEM graduates to STEM jobs. To meet its STEM workforce needs, Maryland is forced to rely upon imported STEM talent, a source that is becoming less reliable as more states seek to grow their knowledge-based economy.[46]

Maryland, with its strong public and private two- and four-year colleges and universities, has the potential to produce the workforce needed to fill the high-tech, high-paying jobs that exist in the state. To succeed, Maryland must increase the number of interested, qualified, and motivated students prepared to take advantage of its highly regarded education institutions. Over the past four years, with the Governor's and General Assembly's support, the University System of Maryland and Morgan State University have taken steps to increase access to college for more Maryland students by freezing tuition for in-state undergraduates, moving the state from having the sixth highest tuition in the country to 18th highest. However, we need to do more to enlarge the pool of STEM undergraduates and to bolster the production of STEM graduates. According to research, robust innovations in curriculum, meaningful capstone experiences, and strong networking opportunities are among the keys to keeping the best and brightest students in the state.[47]

With respect to graduate study, in addition to traditional pathways that lead to a life in research, there is a huge demand for STEM workers trained at the graduate level whose careers will be quite different from traditional research careers. New professional science master's programs (PSM) are designed to respond to the changing needs of industry. These programs do not displace the classical master's program; rather they are developed to serve the needs of students who require a different graduate experience for the workplace.[48]

Maryland's efforts to attract the best and the brightest college students into STEM fields, including teaching, lag behind efforts in other states. Ohio's Choose Ohio First Scholarship Program is a model created to identify and recruit Ohio residents into the fields of STEM, STEM education, and medicine. Such a program implemented in Maryland—Choose Maryland First—would expand the pipeline in these career tracks. Maryland must aggressively recruit and support not only the best and brightest students, but also overlooked students with the potential for college- and career-success in STEM fields.

As the Maryland high school demographics change over the next two decades, Maryland will need to draw more heavily on its population of minority and economically disadvantaged students to meet its demand for STEM-ready workers. Historically, these students have been under-represented in the STEM education pipeline. The state must expand its efforts to reach across the entire state to seek potential STEM students, especially in traditionally underserved and under-represented communities. And, it must provide higher education institutions with the financial resources they need to increase their capacity to successfully guide students through a STEM major, ensuring that they have the knowledge and skills to enter and succeed in a Maryland STEM career.

Recommendation 5: Actions, Benchmarks, and Timelines

Increase enrollment in STEM programs from 20,000 to 25,000 a year.

- ✔ Expand STEM programs at Maryland's two- and four-year colleges and universities with the goal of increasing STEM enrollment from 20,000 to 25,000 students per year. This growth would focus on engineering, information technology, bioscience, and environmental sciences. (2010)
- ✔ Establish a more robust link between higher education and GWIB to ensure that both two- and four-year colleges have programs aligned with Maryland's documented and anticipated STEM workforce needs. (2015)
- ✔ Expand statewide associate degree programs to include high demand fields including Engineering and Biological Sciences. (2012)
- ✔ Expand the number of programs available through online education and at Maryland regional higher education centers from approximately 20 to 30. (2013)
- ✔ Expand Professional Science Master's degree programs from 6 to 12. (2013)
- ✔ Maximize use of existing scholarship/grant pools by ensuring that more low-income students are informed and meet qualification criteria (i.e.: Academic Competitiveness and SMART Grants). (2012)
- ✔ Seek federal and private funding to establish Choose Maryland First Scholarship Program. (2010)

Recommendation 6:

Boost Maryland's global competitiveness by supporting research and entrepreneurship.

According to multiple national measures, Maryland is highly ranked nationally in its research and development (R&D) spending, in its science and technology workforce, and in its efforts to lead "the US transformation into a global, entrepreneurial and knowledge- and innovation-based New Economy . . . "[49] It has unique advantages over its competitor states as it is home to many federal agencies and laboratories, and it will soon experience an expansion of these heavily STEM-dependent installations due to the government's BRAC initiative.

Biotechnology and information technology, and especially information security, which are already strong components of Maryland's economy, will grow with new investments by the government and private sector, enhancing our technology development opportunities. The continued expansion of federal facilities will provide additional R&D opportunities in the life sciences, engineering, drug development, vaccines, information technologies, MEMS (Micro-Electro-Mechanical Systems) technologies, and nanotechnology. The opportunity for Maryland to grow exponentially as a center for research, discovery, and innovation is at hand.

With its burgeoning R&D opportunities, Maryland is positioned to become a national powerhouse in STEM-based economic growth and job creation, especially among its research and doctoral intensive universities within the USM, Morgan State University, and Johns Hopkins University. The state's major impediment to fully capital-

izing on its R&D prowess is its poor performance in translating its R&D into new economic activities and startup companies. Research commercialization efforts of Maryland institutions of higher education are not as effective as compared to its peer institutions.

Recently, the USM established a Task Force on Research and Economic Competitiveness to study the state's and USM's strengths and weaknesses in translational research and the ability for such research to impact economic growth and job creation. USM Chancellor William E. Kirwan charged this task force to make recommendations regarding the expansion of Maryland's high-tech research efforts, to propose economic development initiatives that would benefit the state, and to identify deficiencies in the USM's and the state's R&D commercialization efforts. With representatives from USM institutions, the Department of Business and Economic Development, venture capitalists, entrepreneurs, and private sector CEOs, the Task Force observed that:

> ". . . while Maryland has several outstanding public and private universities that compare very favorably with institutions in competitor states in garnering external support for research, Maryland's institutions have historically been less successful in transferring research discoveries to the marketplace. Additionally, while Maryland offers a number of programs and incentives to encourage and support the creation of start-up companies in Maryland, those programs do not provide sufficient support for the technology transfer efforts of Maryland's major public and private universities. Clearly, additional investments are needed if higher education in Maryland is to become truly competitive in technology transfer."[50]

The Task Force adopted the creation of 325 new Maryland companies over the next 10 years as its primary economic development initiative goal to enhance significantly the direct economic benefit to the state coming from the R&D efforts of its research universities. Additionally, the USM Task Force proposed that the state create five world-class Research Centers of Excellence that would conduct high-level research in technical fields, promise substantial economic benefits for the state, and become global leaders in their fields.

With increased federal funding to support university-based research, the proposed statewide Research Centers of Excellence could be up and running in the near future. While most of the funding for the centers would come from federal grants, it would be important for the state to provide a modest amount of matching funds as part of the grant proposal process. Other states are developing Centers of Excellence and Research Clusters—the Georgia Research Alliance and the Florida Biotechnology Initiative, as examples—to compete for federal research and development dollars and to expand their research capabilities and their economic development potential.

The Governor's Stem Task Force has benefited from the work of the USM Task Force and supports the general concepts proposed by the USM group. As a result, the Governor's group recommends that the centers of excellence concept be broadened to include Johns Hopkins University and Morgan State University as full participants.

In response to its charge to identify deficiencies in Maryland's economic development infrastructure, the USM Task Force noted that the USM has fewer resources devoted to technology transfer than major research universities in the highest performing states, and the commercialization outcome for the state reflects this lack of resource commitment. A similar deficit exists at Morgan State University. To remedy this situation, the USM Task Force recommended, and the Governor's Task Force concurs, that new investment by the state is needed to bring Maryland technology commercialization efforts in line with investments made by other states.

Further, the USM Task Force called for increased funding of the successful Maryland Industrial Partnership (MIPS) program, a nationally recognized applied research program that links the researchers in Maryland universities with Maryland companies. MIPS provides funding, matched by participating companies, for university-based research projects that help companies develop new products. Since 1987, more than 400 Maryland companies have participated in project awards generating more than $16.9 billion in sales while adding jobs to the region and infusing state-of-the-art technology into the global marketplace. The Governor's STEM Task Force embraces this recommendation, with the understanding that all of the state's research universities could participate in this expanded program.

A third recommendation calls for a substantial new investment for Innovate Maryland, a comprehensive statewide effort to increase company formation based on the state's R&D. Innovate Maryland would expand venture capital, legal, and entrepreneurial resource centers across the state to provide proof-of-concept funding; to support technology transfer offices and early-stage funding; and to expand the Maryland Technology Enterprise Institute, the Dingman Center for Entrepreneurship, the ACTiVATE program, and the Maryland Intellectual Property Legal Resource Centers to all institutions of higher education within the state.

With a relatively modest investment, these actions will increase the state's job base and tax revenues, create a more effective workforce, position the state's research universities to be substantially more effective in technology and venture commercialization, and elevate the reputation of Maryland, nationally and internationally, as a center for technology creation and entrepreneurship. State investment also could help the higher education institutions generate 325 new companies by 2020.

Finally, working with the Maryland Congressional Delegation, the Governor and other regional partners—such as the Virginia Congressional delegation and the Chesapeake Crescent—should establish a Congressionally-chartered technology commercialization federal lab foundation to help transfer internal research and development in federal labs to the private sector more effectively. With $8 billion of internal federal research and development, Maryland has the nation's highest concentration of federal lab R&D. Increasing commercialization of this sector even slightly by removing legal and administrative barriers will increase technology based economic development in Maryland and the region, while making the U.S. more technologically competitive.

Recommendation 6: Actions, Benchmarks, and Timelines

Increase Maryland's national and international reputation as a center for technology creation and entrepreneurship.

- ✔ Establish five Maryland Research Centers of Excellence of world-class status, focusing on translational research. (2011)
- ✔ Expand the successful Maryland Industrial Partnerships MIPS Program. (2010)
- ✔ Establish Innovate Maryland (2010), to move Maryland into the top five states in terms of economic impact of R&D and to start 325 new companies. (2020)
- ✔ Create a Congressionally-chartered technology commercialization federal lab foundation. (2010)

Recommendation 7:

Create Maryland's STEM Innovation Network to make STEM resources available to all.

Some states are investing in comprehensive physical and virtual STEM networks to promote collaboration among all STEM education stakeholders: P-12 teachers, higher education faculty, business and community leaders, economic development officers, and policymakers. The North Carolina STEM Community Collaborative is that state's effort to connect its stakeholders to each other and to regional and national networks of innovation and policy for the purpose of developing and implementing a sustainable STEM education-workforce-research-economic development strategy for the state.

Interest in Maryland's P-12 STEM education is widespread, with groups from business, professional societies, industry clusters, economic development organizations, federal installations, museums, and higher education seeking to work with the P-12 education community to improve STEM achievement. In addition, Maryland educators in colleges and universities, in P-12 classrooms, at MSDE, in district-level offices, and in non-government organizations are involved in research and practice related to all aspects of mathematics and science teaching and learning: standards, curricula, assessments, teacher preparation, professional development, and accountability. And, across the state, innovative programs, partnerships, and interventions focused on STEM achievement are being implemented by school districts, schools, two- and four- year colleges, non-profit organizations, business, and other STEM stakeholders.

While Maryland has demonstrated a strong commitment to STEM education and workforce development, it is time to leverage that commitment into a sustainable "energy loop" that can draw on its resources and research to inform teaching and learning, and vice versa. Pockets of excellence exist in schools, school districts, and colleges and universities, but unless and until those bright spots are linked into a synergistic network, the state will continue to miss opportunities to build on our successes.

What is needed in Maryland is a mechanism that enhances communications across all stakeholders; builds the state's capacity to maximize the effects of existing programs and policies; and facilitates the review and revision of Maryland's strategy for its STEM education, research, and workplace 'industries.'

To reach these goals takes very well-aligned partnerships. The Task Force recommends that Maryland establish a public/private STEM Innovation Network, with both a physical and virtual statewide presence. There exists a need to provide a platform and environment for education stakeholders to have quality interactions, thereby advancing education quality and opportunities in Maryland. The network will draw on all of Maryland's STEM stakeholders for its design, sustainability, and agenda. It will utilize technology to provide the backbone for communication and dissemination among its members; encourage collaboration, define and solve problems more broadly; and scale up successful innovations more quickly.

Examples of "nodes" on such a network can be seen in many of the recommended actions and benchmarks within this report. The statewide marketing campaign addressed in Recommendation 1 is a good example of a "node" on the Maryland STEM Innovation Network. Examples from other recommendations include: establishing professional learning communities between and among teachers and college faculty to enhance teacher retention (found

in Recommendation 2); regional professional development collaborative resource networks (found in Recommendation 3); online and regional higher education programs for adult learners (found in Recommendation 4); web-based experiential learning programs (found in Recommendation 5), and Innovate Maryland (found in Recommendation 6).

Other potential "nodes" on the innovation network could include:

- Information sharing/research
- Services to teachers and students (internships, mentoring, tutoring)
- Working groups/Affinity groups
- Teacher Recruitment Center
- Economic development connections for career choices

Recommendation 7: Actions, Benchmark, and Timelines

Establish the Maryland STEM Innovation Network. (2010)

- ✔ Identify Maryland STEM stakeholders to develop the charter for Maryland's STEM Innovation Network. (2009)
- ✔ Seek public and private funding to launch and establish the STEM Innovation Network. (2011)

Budget Impact Analysis

In a climate where the fiscal realities require responsible public officials to conserve resources and make the wisest possible investments, the Governor's STEM Task Force recommends an implementation strategy that prioritizes the less expensive and more important actions, and rolls out a model for ramping up the implementation of various elements of this comprehensive STEM Strategic Plan in four categories: no cost to the state, low cost to the state, moderate cost to the state, and full funding of the plan (figure 1).

Figure 1 lists the seven recommendations and key actions that have been recommended by the Task Force. The four options for funding are in the top row of the chart: (no cost, low cost, moderate cost, full funding). On the chart the high priority items have dollar values; (Y) indicates federal and/or private funding is required.

Figure 1 can be interpreted by reading down the first column of "no cost" elements (no cost to the state). Many of these action items have a cost, but the Task Force strongly urges the Governor to aggressively pursue federal funding ("Race to the Top" and other programs) for many of the recommendations. In Figure 1, for example, Recommendation 2, action number 4 (implement a teacher induction program for STEM teachers) has a significant cost; however, numerous federal grant programs are available to provide initial support for such programs. The Task Force recommends that the state immediately initiate a coherent state effort to secure federal grants in the first year of this strategic plan.[51]

If the state can commit to low-cost implementation (column 2), the chart lists the actions considered to be the highest priority by the Task Force. Those items are given state dollar amounts. For example, with a low cost total of $2.7 million, the state could begin to expand Maryland's PDS network, establish the STEM Teach Program, establish the Regional Professional Development Collaborative Resource Networks, establish a STEM Experiential Learning Network, expand STEM programs in higher education, expand online programs, expand the MIPS program (Maryland Industrial Partnerships), and establish the STEM Innovation Network.

Obviously, these recommendations will require more funds than the state can currently provide. While Figure 1 illustrates the state costs, Figure 2 illustrates how the full cost of implementation would be distributed across three separate funding sources: state, federal, and private.

Maryland is poised to become a national leader in STEM education and research primarily because of the strong collaborations that already exist in the state across education and industry. The recommendations offered here represent broad stakeholder commitment to a comprehensive STEM strategic plan for the next five years.

FIGURE 1 — The Governor's STEM Task Force

	FY 2011 Source of Funds				FY 2012-2015 Source of Funds			
	No cost	Low cost	Moderate cost	Full funding	No cost	Low cost	Moderate cost	Full funding
RECOMMENDATION 1: Align P-12 STEM curriculum with college requirements and workplace expectations in order to prepare all students for postsecondary success								
TOTAL STATE FUNDS Recommendation 1	**TBD**	**TBD**	**TBD**	**TBD**	**TBD**	**TBD**	**TBD**	**TBD**
RECOMMENDATION 2: Triple the number of teachers in STEM shortage areas who are prepared in MD programs and increase their five-year retention rate to 75% from the present estimated rate of 50%, and enhance the STEM preparation and aptitudes for elementary and early childhood teachers.								
Actions, Benchmarks, and Timelines:								
1. Expand Maryland's PDS		500,000	500,000	500,000		2,000,000	2,000,000	2,000,000
2. Establish STEM-Teach		500,000	1,000,000	1,500,000		875,000	1,750,000	3,500,000
3. Expand certification programs for STEM Career Changer Scholarship Program	Y	Y	Y	Y	Y	Y	Y	Y
4. Implement a teacher induction program for STEM teachers	Y	Y	Y	Y	Y	Y	Y	Y
5. Establish a school-based administrative program - STEM Coordinator Program	Y	Y	Y	Y	Y	Y	Y	Y
6. Convene panel to recommend compensation incentives in STEM shortage areas	NO COST							
7. Expand learning communities	Y	Y	Y	Y	Y	Y	Y	Y
TOTAL STATE FUNDS Recommendation 2	**0**	**1,000,000**	**1,500,000**	**2,000,000**	**0**	**2,875,000**	**3,750,000**	**5,500,000**
RECOMMENDATION 3: Ensure that all P-20 mathematics and science teachers have the knowledge and skills to help all students successfully complete the college- and career-ready curriculum.								
Actions, Benchmarks, and Timelines:								
1. Establish Maryland STEM Teacher Summer Fellowship Program	Y	Y	Y	Y	Y	Y	Y	Y
2. Establish Regional Professional Development Collaborative Resource Networks		100,000	125,000	250,000		250,000	500,000	1,000,000
3. Establish a Maryland Redesign of Teacher Education Task Force	NO COST							
4. Develop/Implement a statewide STEM endorsement for elementary teachers	NO COST							
TOTAL STATE FUNDS Recommendation 3	**0**	**100,000**	**125,000**	**250,000**	**0**	**250,000**	**500,000**	**1,000,000**

	FY 2011 Source of Funds				FY 2012-2015 Source of Funds			
	No cost	Low cost	Moderate cost	Full funding	No cost	Low cost	Moderate cost	Full funding
RECOMMENDATION 4: Provide STEM internships, co-ops, or lab experiences for all interested high school and college students to jump-start their successful transition to the workplace.								
Actions, Benchmarks, and Timelines:								
1. Develop and distribute information and materials to students promoting STEM education and careers.	Y	Y	Y	Y	Y	Y	Y	Y
2. Establish a STEM Experiential Learning Network		100,000	100,000	100,000		100,000	100,000	100,000
3. Conduct employer satisfaction surveys	NO COST							
4. Increase STEM internship participation thru Internship Scholarship	Y	Y	Y	Y	Y	Y	Y	Y
TOTAL STATE FUNDS Recommendation 4	0	0	0	0	0	0	0	0
RECOMMENDATION 5: Increase the number of STEM college graduates by 40% from the present level of 4,400 graduates by 2015.								
Actions, Benchmarks, and Timelines:								
1. Expand STEM programs in higher education		1,000,000	1,500,000	3,000,000		1,500,000	3,000,000	6,000,000
2. Establish links between higher ed and GWIB	NO COST							
3. Expand statewide associates programs	Y	Y	Y	Y	Y	Y	Y	Y
4. Expand online programs available		100,000	150,000	200,000		100,000	200,000	400,000
5. Expand Professional Science Master's degree programs	Y	Y	Y	Y	Y	Y	Y	Y
6. Maximize use of existing scholarship/grant pools	Y	Y	Y	Y	Y	Y	Y	Y
7. Establish Choose Maryland First Scholarship Program	Y	Y	Y	Y	Y	Y	Y	Y
TOTAL STATE FUNDS Recommendation 5	0	1,100,000	1,650,000	3,200,000	0	1,600,000	3,200,000	6,400,000
RECOMMENDATION 6: Boost Maryland's global competitiveness by supporting research and entrepreneurship								
Actions, Benchmarks, and Timelines:								
1. Establish five Maryland Research Centers of Excellence*			1,000,000	2,000,000		1,000,000	2,000,000	3,000,000
2. Expand Maryland Industrial Partnership MIPS Program		250,000	500,000	1,000,000		X	X	X
3. Establish Innovate Maryland	Y	Y	Y	Y	Y	Y	Y	Y
4. Create a commericialization federal lab foundation	NO COST							
TOTAL STATE FUNDS Recommendation 6	0	250,000	1,500,000	3,000,000	0	1,000,000	2,000,000	3,000,000
*NOTE: State allocation will be made after receipt of $5M in Federal funds								
RECOMMENDATION 7: Create Maryland's STEM Innovation Network to make STEM resources available to all.								
Actions, Benchmarks, and Timelines:								
1. Develop the charter for STEM Innovation Network	NO COST							
2 Establish the STEM Innovation Network		166,666	166,666	166,666	333,332	333,332	333,332	333,332
TOTAL STATE FUNDS Recommendation 7		166,666	166,666	166,666	333,332	333,332	333,332	333,332
TOTAL STATE FUNDS ALL RECOMMENDATIONS	**0**	**2,616,666**	**4,941,666**	**8,616,666**	**333,332**	**6,058,332**	**9,783,332**	**16,233,332**

FIGURE 2 — The Governor's STEM Task Force

FY 2011
Source of Funds

	State	Federal	Private	Total
Recommendation 1	Cost Estimates to be determined after the College Success Task Force issues its report			
Recommendation 2	$ 2,000,000	$ 450,000	$ 250,000	$ 2,700,000
Recommendation 3	250,000	500,000	0	750,000
Recommendation 4	100,000	100,000	100,000	300,000
Recommendation 5	3,200,000	1,000,000	1,000,000	5,200,000
Recommendation 6	3,000,000	12,850,000	2,850,000	18,700,000
Recommendation 7	166,666	166,667	166,667	500,000
Total	**$ 8,716,666**	**$ 15,066,667**	**$ 4,366,667**	**$ 28,150,000**

FY 2012-2015
Source of Funds

	State	Federal	Private	Total
Recommendation 1	Cost Estimates to be determined after the College Success Task Force issues its report			
Recommendation 2	$ 5,500,000	$ 800,000	$ 0	$ 6,300,000
Recommendation 3	1,000,000	2,000,000	0	3,000,000
Recommendation 4	100,000	400,000	400,000	800,000
Recommendation 5	100,000	400,000	400,000	800,000
Recommendation 6	3,000,000	15,000,000	0	18,000,000
Recommendation 7	333,332	533,334	533,334	1,400,000
Total	**$ 16,333,332**	**$ 22,733,334**	**$ 4,933,334**	**$ 43,900,000**

FIVE-YEAR TOTAL BY SOURCE OF FUNDS

State	25,049,998
Federal	37,800,001
Private	9,300,001
TOTAL	72,150,000

Conclusion

Maryland stands at a crossroads. It has a highly educated workforce, a strong technology based economy, a highly ranked K-12 education system, and nationally recognized colleges and universities. By many accounts, Maryland is already a leader in STEM-related workforce development and economic growth. On the other hand, as noted in this report, Maryland faces a number of challenges if it is to enhance and sustain its position as a national leader in the knowledge economy and establish itself as globally competitive in STEM-related education, translational research, economic growth, and job creation.

To realize its potential:

> MARYLAND NEEDS a school system that prepares its children to excel and compete not only on a global scale, but also as full participants in our society, in our civic culture, and as participants in the growth of our economy. Creating such a system calls for recalibrating academic standards and graduation requirements and rethinking how to recruit and retain the most highly qualified, broadly educated teachers into Maryland public schools.
>
> MARYLAND NEEDS a workforce that is highly skilled and innovative, especially in the STEM fields that will drive the economy of the future. If we are to educate our citizens for the jobs of the future, we need to offer the quality of education that will excite and motivate them, introduce them to exciting career possibilities, early and often, through internships and creative summer programs that stimulate our young people to imagine their future, and draw on talented workforce mentors who are willing to share their experiences.
>
> MARYLAND NEEDS to take better advantage of our rich array of federal government laboratories (NASA Goddard, NIST, APL, NIH) and university research facilities (Johns Hopkins, University System of Maryland, Morgan State University) to launch a new wave of entrepreneurial and translational research activities that will catapult Maryland into the high technology marketplace as a global leader.

In addition to the substantive recommendations included in this report, we recommend that the state move forward on an aggressive statewide public awareness campaign to help Marylanders understand the critical importance of STEM education and of the state's economic competitiveness if they hope to enjoy a high quality of life and benefit from a strong, vibrant economy.

Maryland is positioned as well as any state to tap the tremendous potential and creative talents of its citizens and its industries. The recommendations in this report are designed to build the foundations of our future prosperity and global leadership. The recommendations provide a blueprint on how to recruit, train, and retain the next generation for the challenges facing us in the 21st century, building on our capacity for innovation and economic

growth based on exciting, well paying jobs. To be most effective, the recommendations in this report should be benchmarked and monitored by the Governor's P-20 Council annually.

In summary, here are the imperatives coming from our report:

- ✔ *Establish clear credentials*
  - College Career Ready Diploma
  - Redesign of teacher preparation
- ✔ *Tap the brain trust and stop the brain drain: Grow and keep our own*
  - Choose Maryland First Scholarships
  - STEM Career Changer Scholarships Program
- ✔ *Introduce robust innovations*
  - STEM-Teach
  - Induction Program for all STEM Teachers
  - School-based STEM Coordinators
  - Maryland Research Centers of Excellence
  - Innovate Maryland
  - Public Awareness Campaign
- ✔ *Provide meaningful capstone experiences*
  - STEM Experiential Learning Program
  - Maryland STEM Teacher Summer Fellowship Program
- ✔ *Establish networks to support transformations*
  - Regional Professional Development Collaborative Resource Networks
  - Maryland Professional Development School (PDS) Network
  - Maryland STEM Innovation Network
  - MIPS: Maryland Industrial Partnerships Program
- ✔ *Benchmark our progress internationally*
  - Common Core State Standards Initiative

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Maryland will be a national leader,
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