MATH AND SCIENCE IN A CHANGING FUTURE:

The Maryland STEM Initiatives (M-STEM)

Report of the Governor's STEM Education Advisory Committee
Annapolis, Maryland
September 11, 2006

FOREWORD

This report concerns science, technology, engineering and mathematics (STEM) education in Maryland. The Governor's Commission on Quality Education recommended that a statewide Summit on Mathematics, Science and Technology Education be held in response to growing concerns about workforce shortages and the inability of Maryland's students to compete at the highest international levels of mathematics and science. Governor Ehrlich hosted such a Summit[*] on November 17, 2005 at the University of Maryland Biotechnology Institute's Center for Advanced Research in Biotechnology in Rockville, MD. Following the Summit, the Governor appointed an Advisory Committee on STEM Education and charged it with shaping the ideas from the Summit into a recommended plan of action. What follows is the report of the Advisory Committee.

[*] Financial and staff support for the Summit were provided by the National Alliance of State Science and Mathematics Coalitions (NASSMC), using grants from the National Aeronautics and Space Administration (NASA) and the U.S. Department of Education.

Introduction

With the publication this year of Thomas L. Friedman's analysis that *The World is Flat,* and the National Academies' panel report *Rising Above the Gathering Storm,* American leaders have become acutely aware of the need to dramatically strengthen our scientific and technological capacities to ensure our future prosperity as a nation. They have been reminded once again that the key to this is greatly strengthened education in science, technology, engineering and mathematics (STEM). Truthfully, our nation is still "at risk," and the world won't wait.

In Maryland, as in many states, we have known for years that in mathematics and science our students are not generally competitive with the stronger students from major industrialized nations. This puts them at a distinct disadvantage when competing for jobs in the global economy. Our industrial leaders have been telling us they are unable to hire the workforce they need from Maryland schools and colleges. Effects on Maryland business and industry as well as major government laboratories that help drive our economy are being strongly felt. The work of the Governor's Workforce Investment Board (GWIB) has amplified the message from industrial leaders. We have been making noticeable improvements in a number of areas, but we have yet to mount an educational response that is commensurate with the magnitude of the challenges.

The time has come to launch a bold performance-driven statewide effort to raise learning and teaching in mathematics, science, technology and engineering (the STEM fields) to **world-class** levels and to double over the next ten years the number of students graduating from Maryland institutions at all levels who are ready to enter the state's workforce with strong technical backgrounds. As the framework for a statewide effort to reach these ambitious goals, this Advisory Committee recommends three major initiatives:

- *Raising the Bar* – Bringing rigorous mathematics, science, technology and engineering to a broader set of students today, thereby increasing opportunity for our young people and meeting our pressing technical workforce needs; and launching longer-term pilot projects that will expand over time and lead to world-class mathematics and science for all Maryland students.
- *Preparing and Supporting World-Class Teachers* – Recruiting, preparing and retaining the quality teachers we need for us to be internationally competitive in STEM education and the world economy;
- *Mobilizing Maryland* – A major public information/public engagement program to educate and excite students, teachers, parents and policy-makers about the issues we face in education and the workplace, and about the great new opportunities the state's bold initiatives will bring to our people.

To lead these initiatives the Advisory Committee believes that the state needs a new mechanism, the **Maryland Institute of Science, Technology, Engineering and Mathematics (STEM) Education.** To be sustainable, the Institute will be established as a partnership among institutions of higher education, school districts, industry and foundations. Led by a top-level governing board and an operational coordinating council, the Institute will direct efforts in five critical areas: Service to School Districts and higher education, supporting especially district efforts to reach for world-class standards and strengthen their teacher workforces through the highest quality professional development and recruitment and retention of a new cohort of exceptional teachers; Research on STEM education, studying and disseminating research-based knowledge about how people learn and which programs work, so that policy-makers will have the most relevant and useful information for effective and efficient decision-making and students will benefit from the best research-based instruction, K-16; Public Information, developing and running the initiative *Mobilizing Maryland*; Advice to policy makers and the public on critical issues related to competitiveness and STEM education; and Coordination of major programs undertaken as part of the statewide effort to implement the action plan recommended herein. It is recommended that the Institute partnership be launched under the umbrella of the University System of Maryland.

Plan of Action – *Raising the Bar*

At the Governor's November 17, 2005 Summit on STEM Education, there was near-universal agreement that the time has come for Maryland to significantly expand the base of students highly trained in mathematics and science and strive to attain over time world-class performance levels in these subjects. Discussions of expanding the base emphasized strongly the importance of bringing rigorous mathematics, science and engineering to a broader set of students today, thereby helping to expand opportunity and meet our technical workforce needs. These technical workforce needs include the demand for greater numbers of (a) professional mathematicians, scientists and engineers; (b) teachers of mathematics, science and pre-engineering; and (c) a broader technically trained workforce for industry. *As part of a concerted effort to double our education system's output of such young people over the next decade, six more specific initiatives are recommended, after which we describe an additional program that will be needed to reach all the way to world-class standards for all our students:*

STEM Academies. One strategy to assist in bringing rigorous mathematics, science, technology and engineering to a broader set of today's students is the development of the Governor's STEM Academies, which will target the untapped potential of Maryland's students who traditionally have not seen the benefits of studying rigorous mathematics and science in order to pursue careers in these fields. These academies will be highly specialized schools staffed by teachers working along side scientists and mathematicians from universities and businesses. This collaboration establishes a partnership among the Governor's Office, the Institute of STEM Education, The Maryland State Department of Education, local school systems, higher education institutions, Maryland industries with strong engineering or scientific workforces, and the general business and scientific communities. These STEM Academies will offer a unique and rigorous course of study to include student research, exposure to the professional mathematics, science, engineering and technical community, and leadership skills development opportunities. The curriculum will provide a foundation of the knowledge and the advanced skills required for college success and future career opportunities in science, mathematics, engineering and technology. These innovative programs will afford the students access to advanced equipment and technology along with regular interactions with practicing scientists and mathematicians. The development and operation of the STEM Academies will provide a test bed for innovative approaches to learning. The 2007 State budget contained $2M to begin implementing this program. It is being used to create an Academy at Chesapeake High School in Baltimore County and to support nine planning grants for future academies. *The Governor's Advisory Committee recommends that in each of the next five years substantial resources be included in the state budget for developing and enhancing STEM academies. In fiscal '08 these resources should be sufficient to support all proposals of high quality that result from the nine fiscal '07 planning grants.*

Professional Development Centers. *A network of regional STEM Professional Development Centers should be established to support the programs of the STEM Academies. These regional centers should 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. Maryland industry should play a significant role in providing hands-on engineering and science applications for classrooms pre-K through 12. The work of these Centers should be coordinated by the Institute of STEM Education.* [For further detail on these Centers, see pages 11-12.]

Requiring Four Years of Mathematics and Science – At the Governor's November 17, 2005 STEM Education Summit, there was strong support for the idea of requiring four years each of mathematics and science for high school graduation, with exposure to math, science and pre-engineering age-appropriate concepts beginning with pre-K. More than 80% of students in high school report that they want to

continue with higher education. For all students who desire to go to college, it is very important to have continuous mathematical training in high school, because those students who have a lapse in their mathematical education are significantly more likely to need developmental mathematics when they enter college -- which slows down their progress to degree and is debilitating for them and highly expensive for our state. Of those who wish to go into the more scientific or technological disciplines, it is essential that they take substantive mathematics each year in high school, so that they will be ready for the mathematics and science and engineering that await them when they go to college. This is true even for the students taking AP courses. Demand for science education also continues to increase, reaching across biology, chemistry, physics and earth and planetary science. It is particularly important that students have enhanced laboratory experience in these areas. The Advisory Committee makes the following

Recommendation: The State Board of Education should develop a policy and/or guidelines that encourage students to begin rigorous courses in mathematics and science prior to the ninth grade. Further, the State Board of Education should undertake a review of high school graduation requirements to ensure that those students who wish to go into more scientific or technological disciplines take substantive mathematics and science each year in high school. The advice of the Institute for STEM Education should be sought on the relationship of such requirements to the new goals the state is trying to reach and the major STEM initiatives being launched in Maryland.

Pre-Engineering Programs – As awareness of the nation's weakening competitive technological position has grown over the last decade, it has become clear that we have for too long neglected engineering in the K-12 curriculum. Education in the principles and practices of engineering, with exposure to engineering as a pragmatic career option, is integral to preparing the Maryland workforce and making mathematics and science relevant to student's lives. The recent Department of Defense Base Relocation program, in which Maryland is the recipient of numerous new high tech government opportunities, has driven home the point that the K-12 educational program must not only teach students the fundamentals of mathematics and science, but it must also demonstrate the application of these principles to real-world issues, thus inspiring more students to make the personal investment in learning that will give them the option of pursuing engineering careers at the university level. This is a national imperative that was highlighted in the recent National Academies of Science and Engineering publication "Rising Above the Gathering Storm". The Advisory Committee applauds the efforts under way in various parts of the state to give more students exposure to engineering design through programs such as *Project Lead the Way,* but pre-engineering experience must begin well before secondary school. Industrial support in providing age-appropriate engineering applications of science and math can provide faculty and students with a rich appreciation of engineering from the earliest education experience.

Recommendation: The State Board of Education should seek ways to ensure that engineering demonstration, lesson plans, and technical encounters are integrated into the standard science and mathematics curriculum each year. For all scientific and math subjects, relevant engineering examples, and hands-on learning sessions should be provided that will both increase interest in math and science and bring the field of engineering to life for the students. Teachers can draw upon multiple industrial and academic resources available in Maryland and on the Internet to enrich their curriculum. These resources are being made available and updated regularly via the website of the Maryland Business Roundtable for Education.

Increasing STEM Majors in Colleges and Universities – One of the two major goals that grew out of the November 17 Governor's Summit on STEM Education deals with doubling the numbers of students who complete rigorous STEM programs by the end of high school. To be particularly effective in helping meet the state's technical workforce needs, this increased number of well-prepared high school graduates should translate into increased numbers of STEM majors in the state's colleges and universities. But such

translation is not automatic, even as we move toward our K-12 goals. Institutions of higher education need to be aware of the importance to the state's economy of producing more STEM graduates. They need to have programs to keep well-prepared students in the pipeline. Community colleges need to have ambitious programs for attracting into STEM fields students who have traditionally shunned these fields. One thing that will surely help in this regard is increased scholarships for STEM majors. But faculty can also help through organized programs of 'saving' rather than 'weeding out' STEM majors. As part of this effort, everything possible should be done to provide attractive scholarships for STEM majors, the existence of which will act as a "pull", attracting more high school students to study rigorous mathematics and science.

Recommendation: The Governor's Advisory Committee recommends that a large-scale program be designed and launched to attack the basic question, "What can and should be done within Maryland's colleges and universities to significantly increase numbers of successful STEM majors?" It also recommends that the new Institute of STEM Education be charged with working with the Governor's Workforce Investment Board and other industry leaders to support the creation of such a program.

Analytical Data System – The Maryland State Department of Education (MSDE) is in the process of revamping its student and teacher data system. MSDE has a $5.9M grant from the U.S. Department of Education to develop a Maryland Longitudinal Data System (MLDS). One of the key features of the new system will be its use of individual student identifiers enabling us to quickly answer a variety of questions about which we presently lack proper data. One such question, which is of primary concern to the Advisory Committee, is "How many students complete rigorous mathematics and science programs in secondary school?" With the help and assistance of the state's mathematics and science supervisors, the Advisory Committee has developed an estimate, but it is only an estimate. With MLDS and the future help of the 24 school districts we should have much better data concerning this question and be able to track the data over time so that we know whether the state is better meeting its critical workforce needs.

But the Advisory Committee's concern goes well beyond this one question. An analytical system that is composed of data derived from individual student identifiers should enable district and state educational leaders to build a "best practices" capability for every school and district in Maryland. A limited form of such a capability exists now, but use of individual student identifiers will enable educational leaders to group classes, schools, and districts by demographic profile, identify those which are performing well above the norm, assess the systems, materials, technologies and/or pedagogies which undergird that performance, and help those schools and/or teachers with a similar profile which are not achieving at that level to do so.

Maryland has many exceptional teachers and many exceptional schools in virtually every demographic category, facing virtually every challenge, whether from impoverished communities, an inadequate tax base, or concentration of language challenged students. Yet these same educators, these same schools are performing at very high levels. They are doing something right – more often, many things right. The new data system should allow educators and schools to see the exceptional results in schools virtually identical to their own, realize that they are not unique, but rather learn a new way to do what every educator wants to do – reach and educate to their highest personal level, every child.

World-Class Standards--A Pilot Project. In addition to the sorts of new programs just described – programs bolstered by the teacher and public information initiatives in the next two sections – bigger and bolder steps will be required if we are to reach world-class performance levels for Maryland's students. These steps must bring greater coherence to curricula and be aimed at raising performance levels of all students. The plan the Advisory Committee recommends is to start with mathematics and then do science in a second phase.

Mathematics is key to raising performance in all STEM areas to world-class levels and the following bold strategy is proposed:

> *Recommendation: Using a proven world-class curriculum, a large-scale pilot project should be launched by the Maryland Institute of STEM Education in cooperation with as many as possible of the state's 24 school districts, aimed at raising the mathematics learning of all students to internationally competitive levels. If the pilot proves successful after the first few years, it should be expanded to as many of Maryland's schools as possible. Careful research and evaluation, as well as awareness of applicable state and federal laws should help guide the effort.*

These are the six key steps the Advisory Committee envisions for carrying out this recommendation:

1. Immediately begin a small research project to identify proven world-class curricula, large parts of which are importable to Maryland. A preliminary analysis by the Governor's STEM Advisory Committee concluded that such importation is essential if significant progress is to be made at raising mathematics learning to world-class levels in real time. The Committee has done some preliminary research on possible curricula.
2. Launch a pilot project in carefully selected elementary schools from as many Maryland school systems as possible to begin using the imported curriculum for grades K-2. Over the next several years, phase in the curriculum in stages in these schools, starting from the earliest grades and working up the grade levels. Build in an evaluation plan from the beginning.
3. Provide comprehensive professional development for teachers and principals in the selected schools during a one-year preparation period for first uses of the curriculum, and then continue active professional development as the curriculum is implemented in stages, for example grades 3-4 followed by grades 5-6. Develop learning communities to enhance professionalism and progress.
4. Develop a phase-in plan that opens the use of the new curriculum in lower grades to all elementary schools in the state, even as exploratory work on upper grade levels continues in the initial selected schools. Pave the way for all of this through extensive publicity about the program and extensive professional development for teachers and administrators. Control the rate of program expansion by research-driven assessments of the preparedness of the administrators and teaching staffs in new schools admitted to the program.
5. As the initial work in grades K-6 proceeds, identify the curriculum to be used for 7-12 and lay the groundwork for its implementation as soon as the first cadre of students completes grade 6. The research that the Advisory Committee has already done suggest that there may be more than one possible choice for the 7-12 curriculum, even under the constraint that it must fully integrate with the K-6 curriculum.
6. Proceed with implementation of the curriculum up the grade levels, meanwhile expanding its use at lower grade levels, as in step 4.

It is intended that a similar strategy for science education should be developed by the Institute of STEM Education soon after it is established. A starting point for the deliberations could be *A Shared Vision,* the document developed recently by the Maryland Science Supervisors Association (MSSA).

Plan of Action -- *Preparing and Supporting World-Class Teachers*

As Maryland's schools strive toward greater numbers of students completing rigorous mathematics and science programs and eventually world-class student performance levels, there will be greater demands on the state's teachers of mathematics and science, including elementary teachers. They will face the dual challenges of more demanding curricula and more diverse groups of students. We will need to strengthen the skills and effectiveness of existing teachers and we will need to attract into the profession greater numbers of teachers who have enthusiasm for mathematics and science as well as strong content knowledge. In addition, we will need to provide competitive salaries and professional working conditions, giving teachers time to think, plan and learn – conditions necessary for retaining our best teachers and enabling them to do their demanding jobs effectively. These teacher issues are perhaps the most important ones we face in trying to build the base and reach for world-class levels of performance.

Shortages

At present there are serious shortages of qualified teachers of mathematics and science. The shortage of highly-qualified teachers is made evident by two simple sets of data:

A. In 2005, Maryland's 24 school districts sought to hire 1,375 new qualified teachers of mathematics and science, but were able to find only 960. In other words, there is about a 30% shortfall in the supply of new math and science teachers. This general situation has existed for some years and is worsening.

B. Using the definitions established for the federal No Child Left Behind (NCLB) act, 25% of (middle and secondary) mathematics and science classes and 16% of elementary classes are taught by non-highly-qualified teachers.

School districts are energetically trying to improve their recruitment programs and increase their "yield". One superintendent after another told the Advisory Committee of their frustration at not being able to hire the qualified math and science teachers they need, especially ones with strong content backgrounds. The state began the process of addressing challenges of this type some years ago through The Quality Teacher Incentive Act of 1999. This legislation is not, however, focused on STEM areas and the critical need they represent, nor are its numbers quite up-to-date. (For example, it speaks about using $1,000 signing bonuses to attract new teachers, which would not do much in today's highly competitive math and science teacher market.) Other programs that are run by the state department of education (MSDE) and contribute to improved recruiting and retention of teachers are listed in the (annual) Teacher Staffing Report that MSDE publishes. There is a battery of them and they are a positive force. But again, they lack a specific focus on mathematics and science and in the Advisory Committee's opinion they do not reach high enough or far enough. There is a need to review all of these programs and requirements with an eye to targeting STEM areas and up-dating dollar amounts. But a great deal more than reviewing and updating needs to be done.

Finding 200 Additional New STEM Teachers Each Year

The 2005 National Research Council report, "Rising Above the Gathering Storm", headlined one of its calls to action with, "Ten Thousand Teachers; Ten Million Minds." The intent of the exhortation was to call for 10,000 new highly qualified teachers of mathematics and science in the United States every year for the next decade, and through their skills to reach 10,000,000 young minds. Based on Maryland's share of the U.S. population, this scales to 200 new highly-qualified teachers of mathematics and science every year for the next decade, through whose efforts we will reach 200,000 young minds. It is fair to say that, as a call to action, "Two Hundred Teachers, Two Hundred Thousand Minds" is not much of a "grabber" line. But make

no mistake about it, this represents a very demanding goal for the state of Maryland. It is a goal that the Advisory Committee feels Maryland must take very seriously. The initial focus must be on the teacher part of it, of course.

Where will these new, highly-qualified and highly-motivated teachers come from? The answer is, "From inside and outside the state, from colleges of education and alternative sources. But it will take a large battery of aggressive programs to attract the people we need." The Governor's STEM Education Advisory Committee urges that six steps should be taken to help attract more highly capable people into teaching in STEM fields.

Recommendation: Each year for the next decade, 200 multi-year college scholarships should be provided to young people who intend to become teachers of mathematics and science.

Half of these may be available under federal programs recently launched. But half or more of them should be provided by the State of Maryland as Governor's STEM Teaching Scholarships and carry with them certain conditions, namely, that the student: (a) is majoring in a STEM field; (b) has an approved plan for completing the STEM degree and teacher certification in 5 years; (c) agrees to serve as a Maryland public school STEM teacher, at least one year for each year of scholarship money received; and (d) agrees to repay any scholarship money that is not matched by such service.

Recommendation: The Maryland Institute of STEM Education and the Governor's Workforce Investment Board should help develop and launch an aggressive industry-led program of utilizing scientifically-trained retirees from industry and government as STEM adjunct teachers in Maryland.

There is a very large pool of mathematical, scientific and engineering know-how in the workforces of Maryland industry and the many government laboratories and facilities around the state. Large numbers of them are retiring in the near future. At NASA alone, a significant percentage of the workforce is retiring in the next 5-10 years. These individuals represent a resource that ought to be tapped as much as possible to participate as teachers in Maryland's STEM Education Mobilization. This may require development of a fast-track certification program for certain types of teachers. Great ingenuity and flexibility should be used in designing both the recruitment and certification aspects of this program. One possible use of retirees might be as AP teachers or teachers in other advanced programs.

Recommendation: Schools and school districts should make more extensive use of specialized teachers in order to improve instruction and lighten the loads and decrease the demand for traditional classroom teachers.

The concern in this recommendation is based on the Advisory Committee's understanding of what is going to be required for us to reach the demanding goals in STEM education that the Committee has recommended. The point being made here is not about certification, even though alternative forms of certification may be involved. The point is that we are not going to reach world-class performance levels in mathematics education unless we make extensive use of elementary mathematics specialists, as is done in the countries that outperform us in international comparisons. Such teachers are used extensively in a number of states, including our next-door neighbor, Virginia. We would be far better able to infect students with the enthusiasm and ideas of science if we had and utilized a cadre of elementary science specialists. We need to get ambitious programs underway as soon as possible to prepare and certify such elementary specialists. Such specialists could be described as 'elementary teachers and then some'. But other types of specialized 'assistant' teachers with less demanding preparation can and should be utilized. Where memorization and drill are important – and this is true in many places in mathematics and science – drill and memorization teachers can be utilized. They would be something akin to strength coaches on a football team. Still another type of specialized teacher should be the AP or International Baccalaureate teacher, someone such as a

retiree from industry who has exceptional content knowledge but not perhaps the full range of teacher skills necessary for managing a middle school class in the inner city. Such specialized teachers are only going to be utilized by the schools if there is encouragement to do so. On-going interaction between school district teachers and staff on the one hand and leaders of the major STEM initiatives on the other could help promote use of specialized teachers. One responsibility of the Institute of STEM Education will be to see to it that these interactions occur regularly. Groups such as the Maryland Council of Supervisors of Mathematics (MCSM) and the Maryland Science Supervisors Association (MSSA) can play an important role here.

Recommendation: Legislation should be developed that permits school districts to make strong use of differential salary scales, paying up to 10% more for highly qualified teachers in STEM fields, and offer $5,000 or more signing bonuses to new teachers with strong STEM content backgrounds.

We are in a critical situation and must do everything possible to attract capable young people into teaching, especially in fields like mathematics and physics where more serious shortages exist. The differential pay should be large enough that word of it trickles down to young people thinking about careers in teaching. Signing bonuses should be large enough that word of them also trickles down to these young people. The bonuses should be viewed not only as means to successful recruiting but also as attractions to future prospects. The state should allow as much flexibility in this as possible, recognizing the pressures school districts are under and the importance of having our STEM initiatives succeed.

Recommendation: The State Board of Education should do everything possible to speed up the teacher certification process and make it even more flexible than it now is, especially with regard to fast-track certification of individuals with strong content backgrounds and special types of teachers. In deciding what to do and when to do it, the Board should lean heavily on the advice and counsel of the Institute of STEM Education.

We have teacher needs in STEM fields that are critically important for the economic future of our state and we will need to use every strategy at our disposal to deal with these. One thing we must be is fast on our feet. We have conditional certificates, allowing individuals to be brought on board as teachers while working on their certification and we have alternative certification, usable in some cases where individuals are following non-traditional paths to teaching. But we need to further speed up the route to certification, mindful of the pressures that our districts are under. And we need to take account of new types of teachers: elementary specialists, instructional assistants, teaching coaches for drill and memory work, AP teachers, etc. We need to anticipate the more extensive use of these sorts of specialized teachers that our STEM initiatives will require. For this reason, a review of the certification processes that is begun early and works with Institute of STEM Education is our Committee's recommended course of action.

Preparing the Teachers We Need

Maryland teachers that are hired each year come from in-state (60%) and out-of state (40%). The in-state hires are about equally divided between those who are new to the teaching profession and those who are experienced teachers. A March, 2006 study published by the Maryland Higher Education Commission (MHEC) found that the colleges of teacher education in the state could produce significantly more STEM teachers than they now do if they could find the candidates. This underscores the importance of initiatives such as those just recommended to attract more talented young people into STEM teaching. But it also suggests that our universities need to do even more than they are now doing to find STEM teacher candidates. The Governor's STEM Education Advisory Committee recommends two steps to increase the state's STEM teacher productivity:

Recommendation: Our universities should make teacher education a top priority. As part of this they should launch major initiatives enabling college and university students to obtain a degree in a STEM field and teacher certification in one integrated four-year program – initiatives similar to the UTeach program in Texas and the CalTeach program in California.

If done well, such programs can become a powerful way of recruiting beginning STEM majors into teaching. They also force some rather deep thinking by faculty about the content that is desirable and/or necessary for STEM teachers. This is particularly important as we move into an era of higher content demands in our schools, including those aimed at attaining world-class performance levels. In some universities there is an apparent gulf between the faculties of education and those of the sciences, and this gulf needs to be bridged.

To indicate the sort of progress that can be made with this type of program, we quote a portion of the February 28, 2006 testimony before the Texas Senate presented by Dr. Mary Ann Rankin, Dean of the College of Natural Sciences at the University of Texas, Austin:

"At The University of Texas we have developed a highly successful teacher preparation program for math and science majors called UTeach**.** Research 1 universities have not traditionally assumed much responsibility for teacher training, and indeed prior to establishment of the UTeach program, UT Austin had very few majors pursuing certification: 4 science; 19 math in 1996 from a body of about 8300 majors. It was usually a fall back or last resort for students who did not achieve their primary goal such as admission to medical school, or graduate school, and many who were certified did not actually go on to teach.

In 1997 we decided to create a program that would attract large numbers of strong math and science majors to teaching, and prepare them for success; we believe we have achieved that goal**.** Since the inception of the UTeach program we have doubled the number of math majors and increased by 5-6 times the number of science majors being certified. Enrollment is at 449 students this year and this year's 74 graduates will bring the total number of grads to about 350. Approximately 89% are teaching, planning to teach, or actively searching for teaching positions. 75% of those who graduated in 2001 or before are still teaching."

California's CalTeach program is similar in spirit but organized somewhat differently. It has exceptionally strong support from industry. It should be emphasized that both of these programs are interdisciplinary in character and function well only because of close cooperation among faculties in disciplinary sciences and in education.

The Advisory Committee regards STEM (Science, Technology, Engineering and Mathematics) as more than the sum of its parts. STEM, as educators and content experts here in Maryland and across the nation increasingly understand it, is a "metadiscipline," focusing on learning experiences that require not only knowledge of STEM's constituent disciplines but the ability to apply that knowledge to real-world problems. It involves students in the processes of discovery and invention, and in creative thinking. In a STEM approach to education, students engage authentic problems that require them to draw on their prior knowledge in mathematics and science, and they are highly motivated to acquire the new knowledge needed to solve the problems at hand. A curriculum based on this understanding of STEM develops ways of thinking and problem-solving that lay the foundation for scientific inquiry, technological innovation, and the pursuit of careers that respond to the rapidly changing demands of our 21st-century economy.

Recommendation: Maryland should evaluate the content and efficacy of the state's four-year teacher preparation programs, with an eye to increased content demands in STEM areas, the roles of specialized teachers of various sorts, and the roles of the STEM Professional Development Centers. A focused study of teacher education programs and their effectiveness should be started as soon as possible and carried out in close consultation with the Institute of STEM Education and in close coordination with the review of teacher certification recommended above.

Some of the questions that will need to be dealt with are these: Are we turning out teachers with sufficient content knowledge to bring rigorous mathematics and science to a significantly larger group of students than we now do? Will our teacher graduates be able to handle the demands of world-class curricula to be used in the major pilot projects? Do we prepare elementary math and science specialists? If not, how are we going to do so? What additional resources will be required? Should there be programs to prepare specialist teachers of other types? How can the recruitment programs of our teacher colleges be strengthened? How strongly is each college of teacher education linked to its university's disciplinary faculties in STEM fields?

Retaining the Strong Teachers We Hire

Half of the teachers we hire leave in their first five years on the job. In a period when STEM teacher talent is in short supply, it is absolutely vital that this outflow be controlled. Among the reasons teachers give for leaving, three stand out:

-- teaching salaries are not competitive with those of jobs the STEM teachers can get in industry;
-- the life of a teacher in our system is too hectic and provides too little time for reflective thinking;
-- administrative support is either weak or lacking altogether.

These are not vague and ethereal matters. They are all things that it is within our power to do something about. The Advisory Committee feels that it is imperative to do something about each one of them.

Recommendation: Legislators, school boards and superintendents should develop multi-year plans for raising pay scales for STEM teachers, bringing them more into line with salaries in industry. Maryland should set a goal of lifting teachers' salaries collectively out of the bottom half of the national pay scale.

Industry leaders were among the first to tell the Advisory Committee that it is quite unrealistic to think that we can have the teacher workforce we need without paying competitive salaries. It is unacceptable to continue having teachers in the lower half of salaried workers when they are the frontline of our attempts to keep our state economically competitive. We have gone along for years pretending that this is not so. But it is. The urgency of the situation that our state and our country face in STEM education should be used as the driving force behind a systematic effort to raise salaries to levels that will enable us to attract and retain the teachers we need.

Recommendation: Contact hours for STEM teachers should be reduced so that they have time during the day to work with their colleagues on instructional issues they face. Such a reduction will need to be brought about in steps and stages, but the ultimate goal should be to bring contact hours down to a maximum of 4.

If we are to bring rigorous mathematics and science to significantly more students, and most especially, if we are to raise performance to world-class levels, then our teachers need time to think, plan and learn. Research shows us that this is time that teachers have in countries that outperform us in international comparison studies. We must move in the direction of reducing contact hours. Now, it will be pointed out immediately that this might worsen an already difficult shortage of teachers. This merely means that the efforts to attract more teachers and to reduce contact hours need to be carried out in close coordination with one another and that things will take time. A great deal of what a teacher most know and be able to do is learned, not in a university course, but on the job, through discussions with colleagues. We need to try to create "learning communities" within our schools, the analogue of what the Chinese call "research groups" for teachers. We also need to make more extensive use of instructional assistants, adjunct teachers and other types of specialized teachers, who relieve the principal classroom teacher from standing in front of a class all day long.

Recommendation: Schools and school systems need to make certain that they provide the administrative support that teachers need in order to do their teaching properly. In each building the principal should devote significant amounts of time to work with teachers on curricular and instructional matters.

This will require giving principals the support they need in order to be able to spend sufficient time on instructional matters. The life of a principal is such that, without additional help, the time to spend on instructional matters can just 'slip away.' In a period such as the one we are entering in STEM education, attention to instructional matters is too important to be allowed to slide.

Strengthening Teaching

One of the most important ways that we support our teachers and keep improving the quality of our education programs is by supporting the on-going professional development of teachers. New and more comprehensive professional development programs for STEM teachers will be needed all across Maryland as we bring rigorous mathematics and science to greater numbers of students and eventually raise all student performance to world-class levels.

Recommendation: Regional STEM Professional Development Centers should be created across the state as working hubs of the Institute of STEM Education. These regional centers should be linked to school districts and higher education institutions, to support STEM academies and other Raising the Bar initiatives, focusing on the transformation of teaching content knowledge and teaching methods, teacher preparation, and instruction in the science, technology, engineering, and mathematics fields. The work of these centers should be coordinated by the Institute based on in-depth understanding of new STEM initiatives and a comprehensive study of what is already going on in Maryland.

In some cases, the centers will be Professional Development Academies, analogous to teaching hospitals, and would exemplify best practices, prepare the next generation of teachers, strengthen the STEM content knowledge of existing teachers, and engage K-12 students in rigorous and exciting STEM learning opportunities. In essence, the STEM academies will become satellite "lab schools" of the Institute, places where innovative teaching, research on learning, and industry partnerships can flourish and grow.

Each regional center will assist schools in its geographic area while also developing one or more areas of special expertise (such as elementary school mathematics, middle school science, or an integrated secondary school STEM curriculum) that will be made available to schools in other geographic areas through research reports, new curricula, professional development activities, and distance learning channels.

Examples of specific programs and projects that could be offered at the regional centers include:

- *Professional Development focused on content knowledge* – It is crucial that teachers at all levels have deep and current content knowledge. This is especially true for teachers involved in the world-class mathematics pilot project, but it is true across the teaching force. Regional centers and their higher education partners will offer this content in a number of ways, ranging from lecture series to online coursework to summer courses and institutes and experiences in authentic science research labs. University science, mathematics, and engineering faculty will work with university and school-based educators to develop plans for implementation of content knowledge in K-12 classroom instruction.
- *Certification programs for new and continuing science and mathematics teachers* – Academies and regional centers will partner with teacher preparation programs and academic content specialists to offer high quality, streamlined alternative certification programs for career changers and late deciders with a background in science, mathematics, engineering and other related fields. Middle school

teachers who entered the profession with a K-8 certificate and little content expertise will be put through programs to bolster content knowledge, programs such as the one used with math teachers in the state of Wyoming.

- *Mentoring programs for new teachers of science, mathematics, engineering and technology* – Academies and regional centers will coordinate programs that pair new teachers with experienced teachers or practicing scientists. Academies could also provide training to mentors in how to assist new teachers in developing both their pedagogical and content-related knowledge. Consistent with Maryland Teacher Professional Development Standards, academies could provide in-school coaching services to foster job-embedded professional development. Industry could also provide hands-on experiences and mentoring to further enrich the process.
- *Comprehensive teacher induction programs* – Professional Development Centers and the Institute will work with school districts on development and implementation of comprehensive teacher induction programs. Research shows that such programs for new teachers can significantly improve retention rates if they include mentoring by a veteran teacher in the content area; interaction with an administrator trained in and dedicated to instructional development; common planning time with other teachers; a reduced course load for at least the first year; help from a teacher's aide; and participation in an external network of teachers engaged in professional development – a learning community.
- *Teaching fellow programs* – The Institute will create programs for the best teachers of science, mathematics and technology to come for a summer, a semester or a year to further develop their skills and to share their expertise with university researchers and teachers and to prepare for National Board Certification. Activities will expand their role as expert teachers and enhance their capacity to serve as teacher leaders and mentors supporting mathematics, science and technology curriculum development and teacher enrichment in their schools. At the same time, the teaching fellows will work with university and college STEM faculty to develop and disseminate best practices in pedagogical content knowledge across the K-16 spectrum.
- *Leadership development and Teacher Resource Centers*– Specialized programs will be offered for principals, lead teachers, department heads, and other instructional leaders on how to best support the teaching of science, mathematics and technology, including establishing resource centers with a library of printed and electronically accessible materials and classroom equipment.

The first of these regional Professional Development Centers is being created in 2006, using funding obtained by the State Superintendent of Schools.

Recommendation: Over the next five years, the state budget should contain sufficient resources to support development of a network of regional STEM Professional Development Centers whose 'reach' covers all school districts in the state.

Recommendation: The Institute of STEM Education should enlist the cooperation of Maryland's 24 school districts in developing a comprehensive professional development plan for STEM education. This plan should be part of the guidance system for working with the Professional Development Centers.

Mathematics and science curricula vary considerably across the districts, so development of such a plan will be an ambitious and complex undertaking. Obviously the effort will succeed only if the districts see it as a service, supporting them in their efforts to strengthen STEM education.

Plan of Action – *Mobilizing Maryland*

Recommendation: The Maryland Institute of STEM Education should design and operate a major program of public information/public engagement to: (a) educate students, teachers, parents, policy-makers and others about the issues we in Maryland face and about opportunities created by the new STEM initiatives; and (b) engage these constituent groups in the STEM initiatives being launched.

This will be one of the Institute's vital functions, assuring critical awareness of Maryland's priorities and needs in STEM education, innovation and competitiveness and enlisting the support and participation of many people and groups. The audiences for this public information/public engagement outreach go beyond the traditional stakeholders (schools, school districts, universities and colleges) and engage the many concerned publics. In the same way that Thomas Friedman captured the imagination of the broader public with his thesis that "the world is flat," the Maryland STEM public information/public engagement effort should energize the broader Maryland community to support investment and innovation in teaching and learning science, mathematics, engineering and technology. It should help mobilize concerned citizens in support of major new STEM initiatives.

The plan for the large public information effort will need to be developed under the guidance of an experienced professional in the field of public information and public engagement, utilizing the content input of Institute leaders and the experience of state leaders in education and business affairs. It must identify key audiences and the messages that need to reach them and it must identify the means of doing so, i.e., the vehicles for communicating. The plan must take into account the fact that each audience is in a more-or-less constant state of change, so that the tasks of communicating most messages are never really finished. Finally, the plan must seek to engage each audience in the process of pursuing bold STEM education goals.

Audiences and Messages. Who are these audiences and what are the messages? We will not attempt to lay them all out here, because that is part of the complex planning process that will need to go on. But we will say just enough to make clear why an extensive program of engaging the audiences of education is needed.

This report began, just as did the November 17, 2005 Summit on Mathematics, Science and Technology Education, by referring to the calls to action we have seen in books and the public media – such calls as Thomas Friedman's Book, "The World is Flat", and the report, "Rising Above the Gathering Storm", out of the National Academies. These calls to action note that our nation and our state are in critical situations when it comes to scientific and technical manpower – situations resulting largely from our failure to raise the level of education in STEM fields to world-class levels. Thanks to the books and reports plus various Maryland 'summits', including the April, 2006 "Protecting America's Competitive Edge", held at University of Maryland, College Park, these messages are now well-understood by leaders in Maryland business and government. But they are not well understood by the 'general public'. They are not well understood by students in general, or parents in general, or teachers and administrators in general. So, one of the first challenges of the public information/public engagement effort will be to get these messages out to these audiences – get them out in ways that are both meaningful and effective for students, teachers, parents, etc. A particularly challenging part of the effort will be persuading these audiences that we must significantly raise the level of what our young people learn in STEM fields, lest our economic position deteriorate and our young people fail to compete for jobs in today's economy. But it must not sound like purely negative news. A central part of the message must deal with the good things that will happen for the economy and our young people if we do respond to the challenges before us.

The first step in communicating these messages to the citizens of Maryland must be taken by the Governor, followed by other state leaders. Along with these initial communications must go action plans, which contain within them programs to follow up on the messages and motivate key groups to get behind the

specific components of the action plans. This follow up work will be needed for years and it will need to make use of a wide variety of means of reaching and engaging the key audiences of education.

More specific messages will be involved. We must find new ways to bring the excitement of mathematics, science, technology and engineering to our young people. We must make clear to students what the successful completion of rigorous math and science classes will mean for their futures. We must convey the same messages to parents, helping them to take a little bit longer-range view of what 'success' means for their children. We must make clear to teachers why their continuing professional development is so important and why it is vital that we bring rigorous math and science to greater numbers of students. We must convince business leaders to invest more time, energy and resources in lifting up STEM education in Maryland. We must convince college and university faculties to put as much thought and energy into saving STEM majors as they do into weeding them out. We must convince all of these audiences that STEM fields are not for just a few 'select' or 'gifted' students.

Teaching Makes Every Other Profession Possible. *One component of the public information program to be developed by the Maryland Institute of STEM Education should be a statewide campaign to attract STEM teachers. This focus on prospective teachers should describe the opportunities and the rewards of teaching careers, especially in STEM fields*. This will need to be a professionally developed component, visible throughout Maryland and beyond and conducted relentlessly over a long period of time. It will need to involve the school districts in design and implementation, making sure that all involved are singing from the same songbook. Industry should be brought into this, both because of their marketing know-how and because of their financial interest in seeing a fully-qualified teacher in every STEM classroom.

Engagement. Meaningful dialogue about messages must be part of the process. The individuals involved in every program that is run to move STEM education forward, whether it is in a school, college, company or museum, must be part of the communication team. A detailed plan is needed to ensure that there is some consistency of messages across all of these education programs. Creative thinking as well as tact and diplomacy will be needed to gain the alignment necessary. It is this needed alignment and the importance of ensuring that all messages are rooted in a deep understanding of STEM issues that argues for having the Institute of STEM Education run the public information/public engagement program. The Advisory Committee feels that it is as important as any component of the STEM education plan recommended here.

The Special Role of Industry.

On the subject of education, industry speaks with a special voice. Maryland's industrial leaders will be listened to by the public when they speak out about the major issues of STEM education. These leaders must be consulted and listened to at every stage of development of the plan called Mobilizing Maryland. They and their employees, especially those involved in company outreach programs, should be key parts of the public information/public engagement effort. Industry participation will be many-faceted, but the Advisory Committee wants to call attention to two aspects of it.

Recommendation: The Institute of STEM Education should work with the Governor's Workforce Investment Board (GWIB) or some of its member companies to create a mechanism for coordinating industry outreach programs and increasing their focus on bringing more young people into mathematics, science, technology and engineering. Industry can provide executives or engineers in residence to increase levels of understanding and interaction with real-world opportunities in the classroom.

Recommendation: The State of Maryland should give tax credits to businesses that work to support STEM initiatives consistent with the Action Plan presented here.

Plan of Action – *The Maryland Institute of STEM Education*

The Introduction contained one of the Advisory Committee's key recommendations, to create the Maryland Institute of Science, Technology, Engineering and Mathematics (STEM) Education. Its five major areas of focus were described briefly: Service to school districts and higher education; Advice to government and the public; Research; Public information; and Coordination. Throughout this document we have referred to some specific roles the Institute is intended to play in relation to the initiatives proposed herein. These give some idea of the sort of entity that the Advisory Committee has in mind, but very little has been said thus far about the research focus of the Institute, its structure and its proposed location.

Research on Teaching and Learning in STEM Education. At the heart of the Institute will be a research network focused on teaching and learning science, mathematics, engineering and technology. By studying and disseminating research-based knowledge about how people learn and which things work, the Institute will ensure that policy-makers will have the most relevant and useful information for effective and efficient decision-making and students will benefit from the best research-based instruction K-16. The research function will also assure alignment of primary, secondary and post-secondary learning with the STEM needs of the state, and identify, evaluate and pilot world-class STEM curricula.

The Institute will function as an umbrella "network" to connect all the already established research groups or centers at various institutions -- plus individual researchers from all disciplines and policy researchers from government and non-governmental organizations -- into a Maryland Education Research Colloquy or Network. The Colloquy or Network will use all the well-known academic methods to bring Maryland's researchers together into a strongly interactive learning community: colloquia, seminars, joint projects, joint grants, a Web home, listserv, conferences, and even an online journal. The Network will promote especially research on issues tied to action. Examples of research and evaluation initiatives include:

- *Coordination of a state-wide research agenda in STEM instruction:* The Institute will conduct studies to map the terrain of existing research activities in the state and then evaluate and disseminate research-based best practices in elementary and secondary school science, mathematics, engineering and technology education.
- *Assessment of undergraduate science reform initiatives:* The Institute will conduct studies at colleges and universities to determine the effectiveness of curricular reforms to recruit and retain undergraduate STEM majors.
- *Development and assessment of model curricula* – Currently, several existing professional development schools link their professional development to a particular curriculum. The development of model science, mathematics, engineering and technology curricula will provide a focus for new Professional Development Centers. The focus will be on incorporating deep and current content that reflects state and national expectations with engaging and exciting instruction that "turns students on" to the wonders and joys of STEM fields.

Finally, while the priorities for research and project evaluation will be coordinated by the Council, an explicit premise of the Institute is that it will not undertake any program that can be effected equally well (or better) by some other organization or entity. Among the other organizations that play leadership and coordination roles in education, the Institute will be distinguished by its emphasis on and expertise in issues of mathematical and scientific content.

Structure. The STEM Institute Board will be the board of directors of the Institute and will comprise industry leaders, major scientists and community leaders. Selected state officials may also be members, although care must be exercised in this regard because the Institute exists in part to provide objective advice to state government. The Board will maintain the vision of the Institute, set priorities and provide general oversight for all activities of the Institute. Its members must be of sufficiently high stature that the advice of the Institute will be heeded. The STEM Education Coordinating Council will be the operational arm of the Institute. It will translate charges from the Institute Board into specific projects and priorities and coordinate activities and programs of the Institute with those of the key players in STEM education. It will have an Executive Committee that reports to the STEM Advisory Board and is responsible for the agenda and leadership of the Council.

The Coordinating Council will work closely with state agencies, Maryland's K-16 Partnership, the Governor's Workforce Investment Board, and the Maryland Business Roundtable for Education. The membership of the Council will include leaders from business, education and policy who are actively involved in STEM education, bringing to the table the perspectives of state government; public and private higher education; primary and secondary education; private industry; foundations; professional associations; and regional museums, such as the Maryland Science Academy and the National Aquarium. Of particular concern will be linkages to the mathematics and science education associations and the outreach programs of industry and federal laboratories and centers. Council members will not sit as official representatives of other organizations, even though they are selected because of the particular perspectives they bring.

It is expected that the Council may, with Board approval, establish regional and outreach centers in addition to the STEM Professional Development Centers described in the teacher initiative. Some such centers may be in local schools and school districts, if that is felt by the districts to be helpful. The Coordinating Council will function as an operational clearinghouse and build a network that will match the needs of specific schools and school districts to the activities of regional centers in evaluating and disseminating their work. The Coordinating Council will ensure that the professional development, teacher preparation programs and alternative pathways to certification, educational outreach and alignment efforts at each of the Professional Development Centers are grounded in rigorous STEM education and aimed at eventually reaching world-class levels.

Location. In deciding where such an Institute should be located, several important factors need to be balanced, of which we mention only a few. First, it needs to have the strong support of the business and education communities. Second, although a great deal of private money will be needed, it will almost surely require state funding for its core operations, at least in the early years -- and so there must be some form of state accountability. In balancing these considerations, a third matter of primary importance is that the Institute must be able to provide objective advice to state government (and the public). The Advisory Committee feels that it should not, therefore, be under the control of any state department or agency. This is said recognizing that the Institute must work very closely with a large number of state agencies and departments. The Advisory Committee recommends, therefore, that the most practical way of balancing the state role is for the Institute of STEM Education to be launched under the umbrella of the University System of Maryland (USM). Discussions that Advisory Committee members have had with a number of state leaders lead them to believe that in this way sufficient autonomy can be achieved while there is still ultimate state accountability.

Launch. *It is recommended that resources be included in fiscal '08 budget of the University System of Maryland to launch the Institute, with the intention that this will be renewed annually and that the Governor appoint a small group to develop a proposal to the Board of Regents of the University System of Maryland in time so that the Institute can begin operations in July, 2007.* It is important to note, however, that this will be only the 'core' funding for the Institute. Many of the Institute's programs will require significant amounts of additional foundation and corporate funding. The Advisory Committee has already begun preliminary exploration of potential foundation support for the Institute and the major initiatives of the broader action plan.

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