REPORT TO THE PRESIDENT

PREPARE AND INSPIRE: K-12 EDUCATION IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH (STEM) FOR AMERICA'S FUTURE

Executive Report

Executive Office of the President

President's Council of Advisors on Science and Technology (PCAST)

SEPTEMBER 2010

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WASHINGTON, D.C. 20502

President Barack Obama
The White House
Washington, D.C. 20502

Dear Mr. President,

We are pleased to present you with this report, *Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) Education for America's Future,* prepared for you by PCAST. This report provides a strategy for improving K-12 STEM education that responds to the tremendous challenges and historic opportunities facing the Nation.

In preparing this report and its recommendations, PCAST assembled a Working Group of experts in curriculum development and implementation, school administration, teacher preparation and professional development, effective teaching, out-of-school activities, and educational technology. The report was strengthened by additional input from STEM education experts, STEM practitioners, publishers, private companies, educators, and Federal, state, and local education officials. In addition, PCAST worked with the Office of Management and Budget and the Science and Technology Policy Institute to analyze Federal programs in STEM education.

As you will see, we envision a two-pronged strategy for transforming K-12 education. We must prepare students so they have a strong foundation in STEM subjects and are able to use this knowledge in their personal and professional lives. And we must inspire students so that all are motivated to study STEM subjects in school and many are excited about the prospect of having careers in STEM fields. But this report goes much further than that. It includes specific and practical recommendations that your Administration can take that would help bring this two-pronged strategy to fruition. These recommendations fall under five overarching priorities: (1) improve Federal coordination and leadership on STEM education; (2) support the state-led movement to ensure that the Nation adopts a common baseline for what students learn in STEM; (3) cultivate, recruit, and reward STEM teachers that prepare and inspire students; (4) create STEM-related experiences that excite and interest students of all backgrounds; and (5) support states and school districts in their efforts to transform schools into vibrant STEM learning environments.

We are confident that the report provides a workable, evidence-based roadmap for achieving the vision you have so boldly articulated for STEM education in America. We are grateful for the opportunity to serve you in this way and to provide our input on an issue of such critical importance to the Nation's future.

Sincerely,

John P. Holdren
Co-Chair

Eric Lander
Co-Chair

Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) Education for America's Future

Executive Report

The success of the United States in the 21st century – its wealth and welfare – will depend on the ideas and skills of its population. These have always been the Nation's most important assets. As the world becomes increasingly technological, the value of these national assets will be determined in no small measure by the effectiveness of science, technology, engineering, and mathematics (STEM) education in the United States. STEM education will determine whether the United States will remain a leader among nations and whether we will be able to solve immense challenges in such areas as energy, health, environmental protection, and national security. It will help produce the capable and flexible workforce needed to compete in a global marketplace. It will ensure our society continues to make fundamental discoveries and to advance our understanding of ourselves, our planet, and the universe. It will generate the scientists, technologists, engineers, and mathematicians who will create the new ideas, new products, and entirely new industries of the 21st century. It will provide the technical skills and quantitative literacy needed for individuals to earn livable wages and make better decisions for themselves, their families, and their communities. And it will strengthen our democracy by preparing all citizens to make informed choices in an increasingly technological world.

Throughout the 20th century, the U.S. education system drove much of our Nation's economic growth and prosperity. The great expansion of high school education early in the century, followed by an unprecedented expansion of higher education, produced workers with high levels of technical skills, which supported the economy's prodigious growth and reduced economic inequality. At the same time, scientific progress became an increasingly important driver of innovation-based growth. Since the beginning of the 20th century, average per capita income in the United States has grown more than sevenfold, and science and technology account for more than half of this growth. In the 21st century, the country's need for a world-leading STEM workforce and a scientifically, mathematically, and technologically literate populace has become even greater, and it will continue to grow – particularly as other nations continue to make rapid advances in science and technology. In the words of President Obama, "We must educate our children to compete in an age where knowledge is capital, and the marketplace is global."

Troubling signs

Despite our historical record of achievement, the United States now lags behind other nations in STEM education at the elementary and secondary levels. International comparisons of our students' performance in science and mathematics consistently place the United States in the middle of the pack or lower. On the National Assessment of Educational Progress, less than one-third of U.S. eighth graders show proficiency in mathematics and science.

Moreover, there is a large interest and achievement gap among some groups in STEM, and African Americans, Hispanics, Native Americans, and women are seriously underrepresented in many STEM fields. This limits their participation in many well-paid, high-growth professions and deprives the Nation of the full benefit of their talents and perspectives.

It is important to note that the problem is not just a lack of *proficiency* among American students; there is also a lack of *interest* in STEM fields among many students. Recent evidence suggests that many of the most proficient students, including minority students and women, have been gravitating away from science and engineering toward other professions. Even as the United States focuses on low-performing students, we must devote considerable attention and resources to all of our most high-achieving students from across all groups.

What lies behind mediocre test scores and the pervasive lack of interest in STEM is also troubling. Some of the problem, to be sure, is attributable to schools that are failing systemically; this aspect of the problem must be addressed with systemic solutions. Yet even schools that are generally successful often fall short in STEM fields. Schools often lack teachers who know how to teach science and mathematics effectively, and who know and love their subject well enough to inspire their students. Teachers lack adequate support, including appropriate professional development as well as interesting and intriguing curricula. School systems lack tools for assessing progress and rewarding success. The Nation lacks clear, shared standards for science and math that would help all actors in the system set and achieve goals. As a result, too many American students conclude early in their education that STEM subjects are boring, too difficult, or unwelcoming, leaving them ill-prepared to meet the challenges that will face their generation, their country, and the world.

National Assets and Recent Progress

Despite these troubling signs, the Nation has great strengths on which it can draw.

First, the United States has the most vibrant and productive STEM community in the world, extending from our colleges and universities to our start-up and large companies to our science-rich institutions such as museums and science centers. The approximately 20 million people in the United States who have degrees in STEM- or healthcare-related fields can potentially be a tremendous asset to U.S. education.

Second, a growing body of research has illuminated how children learn about STEM, making it possible to devise more effective instructional materials and teaching strategies. The National Research Council and other organizations have summarized this research in a number of influential reports and have drawn on it to make recommendations concerning the teaching of mathematics and science. These reports transcend tired debates about conceptual understanding versus factual recall versus procedural fluency. They emphasize that students learning science and mathematics need to acquire all of these capabilities, because they support each other.

Third, a clear bipartisan consensus has emerged on the need for education reform in general and the importance of STEM education in particular. The 2002 reauthorization of the Elementary and Secondary Education Act, renamed the No Child Left Behind Act, established the importance of collecting data annually about students' and schools' progress in mathematics and reading and tied Federal education funding to progress. The Congress is currently working on reauthorization of this law, with modifications to improve it.

The Obama administration has made education reform one of its highest priorities. The American Recovery and Reinvestment Act of 2009 established four broad "assurances" to improve the K-12 education system, and the administration has worked to fulfill these assurances through competitive grant-making. A historic, state-led initiative – led by the National Governors Association and the Council of Chief State School Officers – emerged in 2008 to forge clear, consistent, and higher standards for mathematics and English language arts education in grades K-12 that can be shared across states. These standards were recently released, and, as of the publication date of this report, 34 states and the District of Columbia had adopted them. There is also considerable interest in the adoption of similar standards for science, which will be essential for improving STEM education.

Purpose of this Report

In the fall of 2009, the President asked his President's Council of Advisors on Science and Technology (PCAST) to develop specific recommendations concerning the most important actions that the administration should take to ensure that the United States is a leader in STEM education in the coming decades. In responding to this charge, PCAST decided to focus initially on the K-12 level. (A subsequent report will address STEM education at community colleges, four-year colleges, and universities.)

There have been a number of important reports related to STEM education over the past two decades, including landmark reports that have called attention to the problem, reviews of the research literature, and recommendations concerning principles and priorities. Our goal is not to redo the work of these excellent reports – indeed, we have relied heavily on their research and findings. Rather, the purpose of this PCAST report is instead to translate these ideas into a coherent program of Federal action to support STEM education in the United States that responds to current opportunities.

The report examines the national goals and necessary strategies for successful STEM education. We examine the history of Federal support for STEM education and consider actions that the Federal Government should take with respect to improving leadership and coordination. Subsequent chapters discuss Standards and Assessments, Teachers, Technology, Students and Schools.

Many of the recommendations in this report can be carried out with existing Federal funding. Some of the recommendations could be funded in part through existing programs, although new authorities may be required in certain cases. Depending on these choices, the new funding required to fully fund the recommendations could reach up to approximately $1 billion per year. This would correspond to the equivalent of roughly $20 per K-12 public school student; or 2 percent of the total Federal spending of approximately $47 billion on K-12 education; or 0.17 percent of the Nation's total spending of approximately $593 billion on K-12 education. Not all of this funding must come from the Federal budget. We believe that some of the funding can come from private foundations and corporations, as well as from states and districts.

Key Conclusions and Recommendations

While the report discusses a range of conclusions and recommendations, we have sought to identify the most critical priorities for rapid action. Below, we summarize our two main conclusions and our seven highest priority recommendations.

All of these recommendations are directed at the Federal Government, and in particular we focus our attention on actions to be taken by the Department of Education and the National Science Foundation as the lead Federal agencies for STEM education initiatives in K-12.

Achieving the Nation's goals for STEM education in K-12 will require partnerships with state and local government and with the private and philanthropic sectors. The Federal Government must actively engage with each of these partners, who must in turn fulfill their own distinctive roles and responsibilities. In this context, we are encouraged by the state-led collaborative efforts and by the creation of private groups, such as the recently formed coalition, Change the Equation.

CONCLUSIONS

TO IMPROVE STEM EDUCATION, WE MUST FOCUS ON BOTH PREPARATION AND INSPIRATION

To meet our needs for a STEM-capable citizenry, a STEM-proficient workforce, and future STEM experts, the Nation must focus on two complementary goals: We must prepare all students, including girls and minorities who are underrepresented in these fields, to be proficient in STEM subjects. And we must inspire all students to learn STEM and, in the process, motivate many of them to pursue STEM careers.

THE FEDERAL GOVERNMENT HAS HISTORICALLY LACKED A COHERENT STRATEGY AND SUFFICIENT LEADERSHIP CAPACITY FOR K-12 STEM EDUCATION

Over the past few decades, a diversity of Federal projects and approaches to K-12 STEM education across multiple agencies appears to have emerged largely without a coherent vision and without careful oversight of goals and outcomes. In addition, relatively little Federal funding has historically been targeted toward catalytic efforts with the potential to transform STEM education, too little attention has been paid to replication and scale-up to disseminate proven programs widely, and too little capacity at key agencies has been devoted to strategy and coordination.

RECOMMENDATIONS

1. **STANDARDS: SUPPORT THE CURRENT STATE-LED MOVEMENT FOR SHARED STANDARDS IN MATH AND SCIENCE**

   The Federal Government should vigorously support the state-led effort to develop common standards in STEM subjects, by providing financial and technical support to states for (i) rigorous, high-quality professional development aligned with shared standards, and (ii) the development, evaluation, administration, and ongoing improvement of assessments aligned to those standards.

   The standards and assessments should reflect the mix of factual knowledge, conceptual understanding, procedural skills, and habits of thought described in recent studies by the National Research Council.

2. **TEACHERS: RECRUIT AND TRAIN 100,000 GREAT STEM TEACHERS OVER THE NEXT DECADE WHO ARE ABLE TO PREPARE AND INSPIRE STUDENTS**

   The most important factor in ensuring excellence is great STEM teachers, with both deep content knowledge in STEM subjects and mastery of the pedagogical skills required to teach these subjects well.

The Federal Government should set a goal of ensuring over the next decade the recruitment, preparation, and induction support of at least 100,000 new STEM middle and high school teachers who have strong majors in STEM fields and strong content-specific pedagogical preparation, by providing vigorous support for programs designed to produce such teachers.

3. TEACHERS: RECOGNIZE AND REWARD THE TOP 5 PERCENT OF THE NATION'S STEM TEACHERS, BY CREATING A STEM MASTER TEACHERS CORPS

Attracting and retaining great STEM teachers requires recognizing and rewarding excellence.

The Federal Government should support the creation of a national STEM Master Teachers Corps that recognizes, rewards, and engages the best STEM teachers and elevates the status of the profession. It should recognize the top 5 percent of all STEM teachers in the Nation, and Corps members should receive significant salary supplements as well as funds to support activities in their schools and districts.

4. EDUCATIONAL TECHNOLOGY: USE TECHNOLOGY TO DRIVE INNOVATION, BY CREATING AN ADVANCED RESEARCH PROJECTS AGENCY FOR EDUCATION

Information and computation technology can be a powerful driving force for innovation in education, by improving the quality of instructional materials available to teachers and students, aiding in the development of high-quality assessments that capture student learning, and accelerating the collection and use of data to provide rich feedback to students, teachers, and schools. Moreover, technology has been advancing rapidly to the point that it can soon play a transformative role in education. Realizing the benefits of technology for K-12 education, however, will require active investments in research and development to create broadly useful technology platforms and well-designed and validated examples of comprehensive, integrated "deeply digital" instructional materials.

The Federal Government should create a mission-driven, advanced research projects agency for education (ARPA-ED) housed either in the Department of Education, in the National Science Foundation, or as a joint entity. It should have a mission-driven culture, visionary leadership, and draw on the strengths of both agencies. ARPA-ED should propel and support (i) the development of innovative technologies and technology platforms for learning, teaching, and assessment across all subjects and ages, and (ii) the development of effective, integrated, whole-course materials for STEM education.

5. STUDENTS: CREATE OPPORTUNITIES FOR INSPIRATION THROUGH INDIVIDUAL AND GROUP EXPERIENCES OUTSIDE THE CLASSROOM

STEM education is most successful when students develop personal connections with the ideas and excitement of STEM fields. This can occur not only in the classroom but also through individualized and group experiences outside the classroom and through advanced courses.

The Federal Government should develop a coordinated initiative, which we call INSPIRE, to support the development of a wide range of high-quality STEM-based after-school and extended

day activities (such as STEM contests, fabrication laboratories, summer and after-school programs, and similar activities). The program should span disparate efforts of science mission agencies and after-school programs supported through the Department of Education funding.

6. SCHOOLS: CREATE 1,000 NEW STEM-FOCUSED SCHOOLS OVER THE NEXT DECADE

STEM-focused schools represent a unique National resource, both through their direct impact on students and as laboratories for experimenting with innovative approaches. The Nation currently has only about 100 STEM-focused schools, concentrated at the high school level.

The Federal Government should promote the creation of at least 200 new highly-STEM-focused high schools and 800 STEM-focused elementary and middle schools over the next decade, including many serving minority and high-poverty communities. In addition, the Federal Government should take steps to ensure that all schools and schools systems have access to relevant STEM-expertise.

7. ENSURE STRONG AND STRATEGIC NATIONAL LEADERSHIP

Stronger leadership, coherent strategy and greater coordination are essential to support innovation in K-12 STEM education. Toward this end, the Federal Government should (i) create new mechanisms, with substantially increased capacity, to provide leadership within each of the Department of Education and the National Science Foundation; (ii) establish a high-level partnership between these agencies; (iii) establish a standing Committee on STEM Education within the National Science and Technology Council responsible for creating a Federal STEM education strategy; and (iv) establish an independent Presidential Commission on STEM Education, in conjunction with the National Governors Association, to promote and monitor progress toward improving STEM education.

PCAST believes that the Nation has an urgent need – but also, thanks to recent developments, an unprecedented opportunity – to bring together stakeholders at all levels to transform STEM education to lay the groundwork for a new century of American progress and prosperity.

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