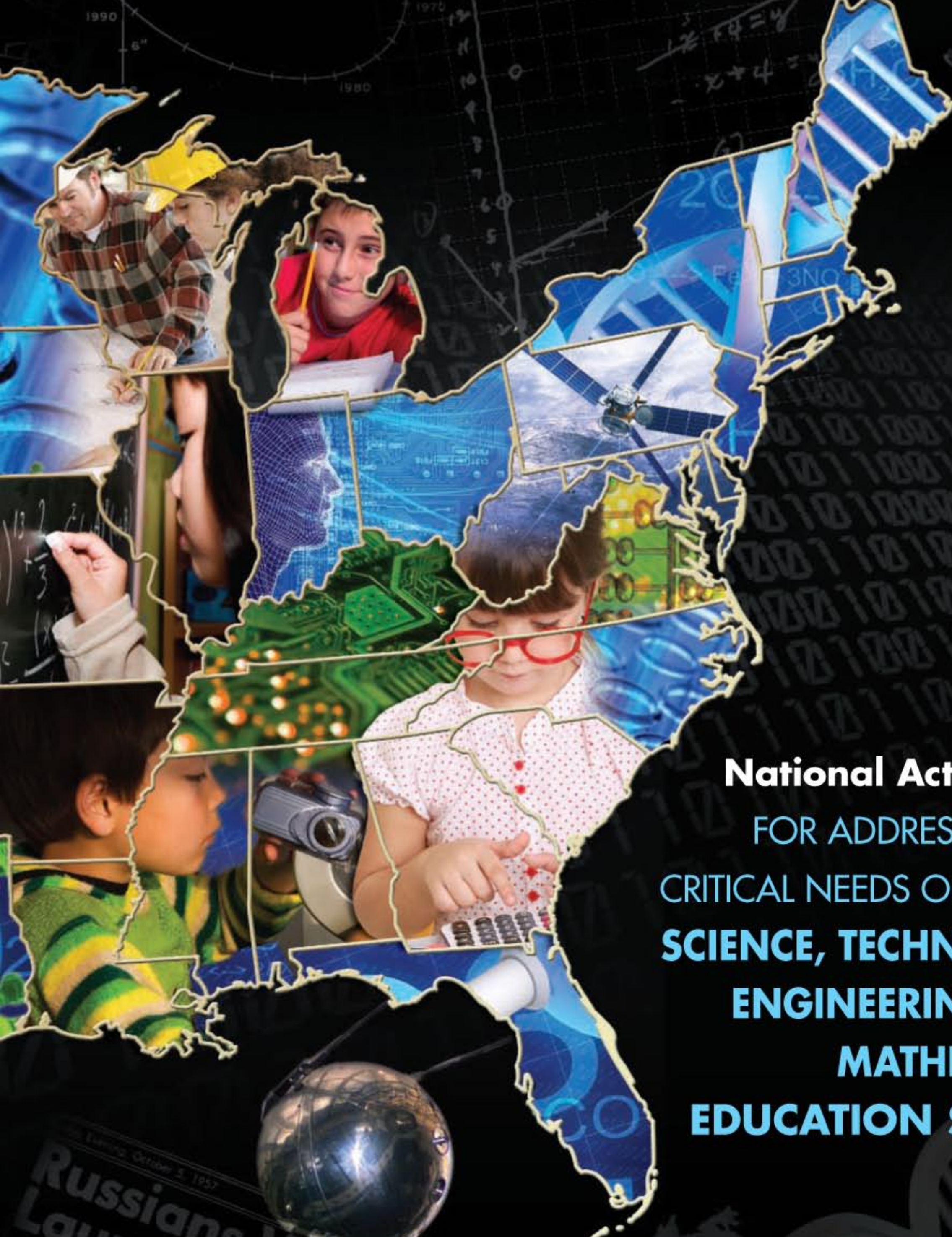
National Science Board



National Action Plan

FOR ADDRESSING THE CRITICAL NEEDS OF THE U.S. **SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS EDUCATION SYSTEM**

October 30, 2007

NATIONAL SCIENCE FOUNDATION · NSB · National Science Board · Est. 1950

Cover Design by Strategic Analysis, Inc., Graphics and Multimedia Services Division

NSB-07-114

A NATIONAL ACTION PLAN

FOR ADDRESSING THE CRITICAL NEEDS OF THE U.S. SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS EDUCATION SYSTEM

NATIONAL SCIENCE FOUNDATION

National Science Board

Est. 1950

October 30, 2007

National Science Board

The National Science Board consists of 24 members plus the Director of the National Science Foundation. Appointed by the President, the Board serves as the policy-making body of the Foundation and provides advice to the President and Congress on matters of national science and engineering policy.

Contents

October 30, 2007

MEMORANDUM FROM THE CHAIRMAN OF THE NATIONAL SCIENCE BOARD

SUBJECT: *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System*

The National Science Board (Board) is pleased to present a national action plan to address pressing issues in U.S. science, technology, engineering, and mathematics (STEM) education. In this action plan the Board identifies priority actions that should be taken by all stakeholders, working together cooperatively, to achieve measurable improvements in the Nation's STEM education system.

The Board believes that the Nation is failing to meet the STEM education needs of U.S. students, with serious implications for our scientific and engineering workforce in the 21st century. Addressing this issue is absolutely essential for the continued economic success of the Nation and its national security. All American citizens must have the basic scientific, technological, and mathematical knowledge to make informed personal choices, to be educated voters, and to thrive in the increasingly technological global marketplace.

The Board, established by Congress in 1950, provides oversight for, and establishes the policies of, the National Science Foundation (NSF). It also serves as an independent body of advisors to the President and Congress on national policy issues related to science and engineering research and education. The Board undertook this project in response to both of these responsibilities and with the urging of Congress. Some portions of the action plan are directed to NSF, and other portions to the Nation as a whole.

This action plan was developed by the Board over nearly 2 years, with input from leaders in STEM education at a series of Board-sponsored hearings, a Board-established advisory committee – the Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics – and the findings of previous reports, panels, task forces, and commissions that have called for a major transformation of STEM education in the United States.

The Board formally unveiled this action plan at the U.S. Capitol Building with Members of Congress, stakeholder groups, and the public in attendance on October 3, 2007. Fittingly, this was on the eve of the 50th anniversary of the launch of the Soviet satellite Sputnik – an event that shocked the world and spurred the American people to take dramatic action to improve STEM research and education. Today we face an equally daunting challenge in the potential economic threats and opportunities posed by globalization. We urge all Americans to recommit to ensuring our STEM education system prepares our children to sustain U.S. preeminence in science and technology for the future.

Steven C. Beering
Chairman
National Science Board

National Science Foundation
4201 Wilson Boulevard • Arlington, Virginia 22230 • (703) 292-7000 • http://www.nsf.gov/nsb email: NSBoffice@nsf.gov

Acknowledgments

The National Science Board (Board) thanks the many members of the science, technology, engineering, and mathematics (STEM) education, research, and policy communities who generously contributed their time and intellect to the development of this action plan. Those who contributed to this action plan are too numerous to mention individually. Participants in the Board-sponsored public Hearings on 21st Century Education in Science, Mathematics, and Technology are listed in Appendix C. Those who submitted written comments on a draft of the action plan during August 2007 are listed in Appendix G.

The Board is particularly grateful to the members of its Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics (Commission) who provided valuable insight from a broad range of expertise and perspectives in STEM education. Commission members Dr. Leon Lederman (Co-Chairman), Dr. Shirley Malcom (Co-Chairman), Dr. Jo Anne Vasquez (Vice-Chairman), The Honorable Nancy Kassebaum Baker, Dr. George Boggs, Mr. Ronald Bullock, Dr. Karen Symms Gallagher, Dr. James Gentile, Dr. Dudley Herschbach, Ms. María Alicia López-Freeman, Dr. Maritza Macdonald, Mr. Timothy McCollum, Dr. Cindy Moss, Mr. Larry Prichard, and The Honorable Louis Stokes all devoted considerable time and intellectual energy to the work of the Commission. The Board recognizes and appreciates their invaluable contributions. Commission meeting participants and working group members are acknowledged within Appendix F.

Dr. Elizabeth Strickland, Sigma Xi-National Science Board Fellow, who spearheaded this project and served as Executive Secretary of the Commission deserves special recognition for her tireless and significant contributions to the formulation of this national action plan. Those staff also deserving recognition are: Ms. Sarah Cana, Ms. Clara Englert, Ms. Ann Ferrante, Ms. Jean Pomeroy, Ms. Jennifer Richards, Ms. Cara Rooney, Ms. Tami Tamashiro, and Ms. Amy Hoang Wrona. The Board's Executive Director, Dr. Michael Crosby, provided leadership and guidance for all Board Office activities related to the effort.

We wish to acknowledge the special contributions of several former and current Board Members who provided essential leadership in the development of this action plan. Former Board Chairman Dr. Warren Washington led the launch of this Board activity and guided the establishment and empanelling of the Commission. Dr. Elizabeth Hoffman, Chairman of the Committee on Education and Human Resources (EHR), shepherded the plan through the EHR Committee in the final stages of its development. Finally, Dr. Jo Anne Vasquez served as the Board's champion and advocate for this effort in her capacity as Commission Vice-Chairman and Member of the Board. Her career as a STEM educator and teacher and as a leader in the preK-12 STEM education community provided her with the unique ability to contribute significantly to the core essence of this national action plan.

A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System

Executive Summary

The United States possesses the most innovative, technologically capable economy in the world, and yet its science, technology, engineering, and mathematics (STEM) education system is failing to ensure that *all* American students receive the skills and knowledge required for success in the 21st century workforce. The Nation faces two central challenges to constructing a strong, coordinated STEM education system:

- Ensuring coherence in STEM learning, and
- Ensuring an adequate supply of well-prepared and highly effective STEM teachers.

In order to direct attention to pressing issues and concerns in STEM education and to coordinate and enhance STEM education across local, State, and Federal programs, the National Science Board (Board) recommends the following:

- The U.S. Congress should pass, and the President should sign into law, an act chartering a new, independent, non-Federal *National Council for STEM Education* to coordinate and facilitate STEM programs and initiatives throughout the Nation, as well as to inform policymakers and the public on the state of STEM education in the United States.
- The President's *Office of Science and Technology Policy* should create a standing Committee on STEM Education within the National Science and Technology Council with the responsibility to coordinate all Federal STEM education programs.
- The *Department of Education* should create a new Assistant Secretary of Education position charged with coordinating the Department's efforts in STEM education and interacting with stakeholders outside the Department.
- The *National Science Foundation* should lead an effort to create a national road map to improve pre-kindergarten to college and beyond (P-16/P-20) STEM education, drawing on its national standing in the science and engineering communities and its expertise in science and engineering research and education.

In recognition of the lead role of local and state jurisdictions in the Nation's P-12 education system, the Board recommends that all stakeholders work together, using the National Council for STEM Education as the focal point, to provide *horizontal* coordination of STEM education among states by:

- Facilitating a strategy to define national STEM content guidelines that would outline the essential knowledge and skills needed at each grade level,
- Developing metrics to assess student performance that are aligned with national content guidelines,

- Ensuring that assessments under No Child Left Behind promote STEM learning, and
- Providing a forum to share and disseminate information on best practices in STEM teaching and learning.

The Board also recommends that all stakeholders promote *vertical* alignment of STEM education across grade levels – from pre-K through the first years of higher education by:

- Improving the linkage between high school and higher education and/or the workforce,
- Creating or strengthening STEM education-focused P-16 or P-20 councils in each state, and
- Encouraging alignment of STEM content throughout the P-12 education system.

Finally, the Board recommends actions that ensure students are taught by well-prepared and highly effective STEM teachers. These include strategies for increasing the number of such teachers and improving the quality of their preparation by:

- Developing strategies for compensating STEM teachers at market rates,
- Providing resources for the preparation of future STEM teachers,
- Increasing STEM teacher mobility between districts by creating national STEM teacher certification standards, and
- Preparing STEM teachers to teach STEM content effectively.

This action plan lays out a structure that will allow stakeholders from local, State, and Federal governments, as well as nongovernmental STEM education stakeholder groups, to work together to coordinate and enhance the Nation's ability to produce a numerate and scientifically and technologically literate society and to increase and improve the current STEM education workforce. Strategies for producing the next generation of innovators are not explicitly addressed in this action plan and will require subsequent study. A coherent system of STEM education is essential to the Nation's economy and well-being.

Introduction

American ingenuity, built on a foundation of science and engineering, has led our country to the forefront of innovation and discovery in the 19th and 20th centuries and has changed the basis of our economy. In the 21st century, scientific and technological innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy. To succeed in this new information-based and highly technological society, all students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past. A particular need exists for an increased emphasis on technology and engineering at all levels in our Nation's education system.

To succeed in this new information-based and highly technological society, all students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past.

Business and industry leaders, governors, policy makers, educators, higher education officials, and our national defense and security agencies have repeatedly stated the need for efforts to reform the teaching of STEM disciplines in the Nation so that the United States will continue to be competitive in the global, knowledge-based economy. Many reports have spoken to this growing crisis over the past 25 years. One of the more recent and most influential is the National Academies' report, *Rising Above the Gathering Storm*, which makes several recommendations for improvements in U.S. STEM teacher quality and student education based on their importance to global competitiveness.[1] Although the recommendations in past reports have been widely praised, their importance and implications have not been appropriately recognized and understood. As a consequence, they have not been fully implemented.

Although the National Science Board (Board) has long been concerned with quality P-20 education in STEM fields, this action plan has its genesis during the development of the 2006 *Science and Engineering Indicators*. The Board noted worrisome trends in STEM education and commented on these in the *Indicators* companion piece, *America's Pressing Challenge – Building a Stronger Foundation*. As a result of its observations and a request from Congress,[2] the Board began to consider developing a national action plan to address the Nation's need for improvements in STEM education. The Board held a series of hearings around the U.S. to gather expert testimony from leaders in STEM education in 2005 and 2006 (see Appendix C).[3] Subsequently, the Board established an advisory Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics (Commission) to provide advice for a bold new action plan to implement the findings of previous reports, panels, task forces, and commissions that have called for a major transformation of STEM education in the United States (see Appendices D and E). The Commission provided its advice to the Board in March 2007 (included as Appendix F). In addition to the Commission's input and the testimony given at the Board's hearings, the Board itself also reviewed the findings of previous panels, task forces, and commissions.

The Board has prepared this action plan based on all the input described above with the goal to improve the Nation's STEM education system. The actions recommended here are not the only possible positive actions that could be taken, but rather are actions that the Board has determined to be priorities nationally. It has long been recognized that to develop the next generation of innovators, the Nation must provide a broad pool of students with the opportunity to acquire a basic understanding of STEM.[4] Thus, this action plan focuses on raising the base level of scientific, technological, and mathematical capacity of *all* students. In FY2008, the Board will begin an effort to focus on the additional specialized needs of preparing the next generation of innovators.

The recommendations in this national action plan, taken together, will be an important first step in the transformation of STEM teaching and learning in the United States. A coherent, coordinated system of STEM education provided by well-prepared and highly effective STEM teachers is essential to the future prosperity and security of our Nation.[5]

Context of the Action Plan

Current Status of the U.S. STEM Education System

Within the current education system, U.S. students are not obtaining the STEM knowledge they need to succeed. As *Rising Above the Gathering Storm* notes, "The danger exists that Americans may not know enough about science, technology, or mathematics to contribute significantly to, or fully benefit from, the knowledge-based economy that is already taking shape around us."[6] Almost 30 percent of students in their first year of college are forced to take remedial science and math classes because they are not prepared to take college-level

Almost 30 percent of students in their first year of college are forced to take remedial science and math classes because they are not prepared to take college-level courses.

courses.[7] International benchmarks, such as the Programme for International Student Assessment (PISA) test,[8] show that U.S. students are behind students in other industrialized nations in STEM critical thinking skills (see Table).

Country	Score	Rank
Finland	548	1
Japan	548	1
South Korea	538	3
Australia	525	4
Netherlands	524	5
Czech Republic	523	6
New Zealand	521	7
Canada	519	8
Switzerland	513	9
France	511	10
Belgium	509	11
Sweden	506	12
Ireland	505	13
Hungary	503	13
Germany	502	15
Poland	498	16
Iceland	495	17
Slovak Republic	495	17
United States	491	19
Austria	491	19
Italy	487	21
Spain	487	21
Norway	484	23
Luxembourg	483	24
Greece	481	25
Denmark	475	26
Portugal	468	27
Turkey	434	28
Mexico	405	29

Table. United States Falls Behind Many OECD* Countries in Science Literacy of 15 Year Olds

SOURCE: M. Lemke, A. Sen, E. Pahlke, L. Partelow, D. Miller, T. Williams, D. Kastberg, and L. Jocelyn, *International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003 Results From the U.S. Perspective: Highlights*. U.S. Department of Education, Center for Education Statistics

* OECD refers to Organisation for Economic Co-operation and Development

In order to provide American students with the STEM knowledge they require, two challenges must be addressed. First, current STEM education in the Nation is not coordinated horizontally among states nor aligned vertically through grade levels. Horizontally, STEM content standards and the sequence in which content is taught vary greatly among school systems, as do the expectations for and indicators of success. Because states have no consensus on what key concepts students should master and should be included in the curriculum at a certain grade level or within a specific content area, textbooks often cover too many topics at too superficial a level,[9] rather than focus on a few key topics in-depth. In our highly mobile society, students who move from one school system to another often miss exposure to critical fundamental concepts in one school and never have a subsequent opportunity to master those concepts.[10] Likewise, state assessments of student achievement vary widely.[11] Vertically, little or no alignment of STEM learning occurs during students' progression through school. Students do not always obtain mastery of key concepts at the elementary and middle school levels, thus limiting academic success at the high school level. In addition, many high schools provide a curriculum that is uninspiring, poorly aligned, outdated, lacking in rigor, and fraught with low expectations. The net result is that almost 30 percent of high school graduates enter college unprepared for first-year coursework[12] or arrive at the workplace without the mathematical, scientific, and technical skills that employers require.[13,14] Today, possessing a high school diploma too often does not signify that a young person will be able to thrive in the global, knowledge-based economy.

Second, the Nation faces a chronic shortage of qualified teachers who are adequately prepared and supported to teach STEM disciplines effectively.[15] Local school systems encounter many barriers to recruiting and retaining high-quality STEM teachers. STEM-trained professionals often do not choose to teach, and too few educators acquire STEM training.[16] Teachers, particularly at the elementary and middle school levels, often do not acquire sufficient STEM content knowledge or skills for teaching this content during their pre-service preparation. Once on the job, many teachers neither receive adequate support during the critical first few years in the classroom, nor adequate mentoring and/or continued professional development opportunities. For STEM-trained professionals, the current job market offers non-teaching career opportunities with substantially higher salaries[17] and often better working conditions than those professionals would receive in teaching careers. Lack of flexibility in teacher compensation restricts[18] how local education agencies compete for and retain qualified candidates.[19] The problem of recruiting and retaining high-quality STEM teachers is often compounded by a lack of adequate facilities and resources needed for effective teaching.

Direct and Indirect Stakeholder Involvement and Coordination

In the United States, education is primarily a local and state responsibility. More than 14,000 local school boards[20] determine local education policy across the Nation, and state governors play a central role in overseeing the education systems in their states. Therefore, any effective strategy for nationwide improvements to STEM education must balance local and state implementation of education policy with a nationally shared aspiration of world-class achievement for all students.

STEM education initiatives and programs presently reside in a variety of state and Federal agencies and the informal learning community, and span pre-K through institutions of higher education. Within the Federal Government alone at least a dozen offices, departments, and agencies contain STEM education programs (see Figure 1),[21] but no consistent Executive Branch forum coordinates these programs.[22] Furthermore, no single entity currently exists to provide critical coordination for STEM education among all those who have a direct role (such as local education agencies and school boards, state boards of education, state governors, and the Federal Government) and those who have an indirect role (such as institutions of higher education, business and industry, teacher unions, the informal STEM learning community, and private foundations).

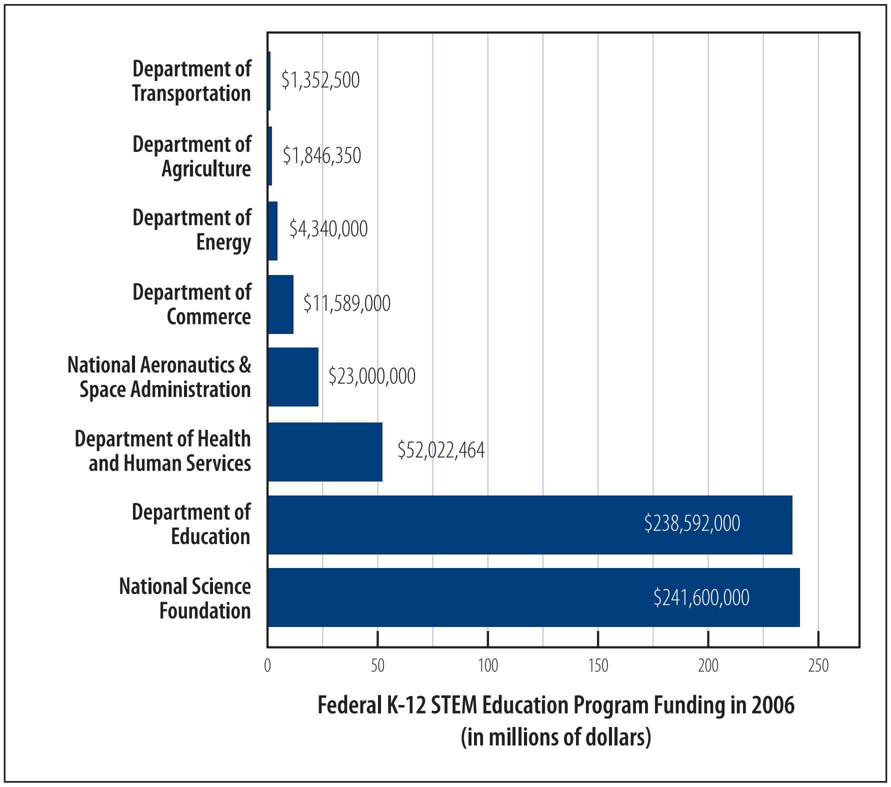


Figure 1. Federal K-12 STEM Education Program Funding in 2006

SOURCE: Department of Education, *Report of the Academic Competitiveness Council,* 2007

Precedent for Embracing Change

Substantial improvements in STEM education in the Nation today will require a commitment of leadership at the local, state, and Federal levels and effective communication and coordination among these levels of government. This type of commitment and coordination is not unprecedented. Two key examples illustrate the way in which restructuring Federal policy can yield improvements in education.

The shock effect of the Soviet's successful launch of Sputnik in 1957 jarred the United States into taking appropriate actions to win the space race. Within a year, the National Aeronautics and Space Administration (NASA) was established by Congress to oversee the development of a successful U.S. space program, and the science advisory system to the President was established to provide continuous scientific and technical advice. Precedent-shattering Federal assistance to education was provided via the National Defense Education Act (NDEA) to the Department of Defense, the National Science Foundation (NSF), and other Federal agencies. New curricula in mathematics and science were researched, field-tested, and implemented, and a unified national movement to improve the teaching and learning of these core disciplines emerged. The number of qualified graduates in STEM fields surged.[23]

Another instructive example is the transformation in the education of children with special needs. Since the early 1970s, substantial improvements have been made nationwide.[24] This transformation was prompted by changes in Federal policy and occurred down to the level of each local education agency. It was achieved through a combination of Federal legislation, court decrees, and Federal funding that required local and state adoption of Federal standards and guidelines.

Substantial improvements in STEM education in the Nation today will require the same type of commitment of leadership at the local, state, and Federal levels and effective communication and coordination among these levels of government. Currently, many of the Nation's governors are leading new state initiatives to address STEM education needs, and the Federal agencies are beginning to take stock of existing diverse and disparate Federal STEM education programs. Congress is drafting and passing numerous pieces of legislation related to STEM education. The window of national opportunity is open for implementing this bold new action plan to move STEM education into the 21st century – the time for all in the Nation to act together to make this a reality is now.

Recommendations

The Board is cognizant that local and state governments bear the ultimate responsibility in the Nation's system of public education. Its recommendations do not challenge the appropriateness of that responsibility. Rather, this national action plan is meant to support and enhance efforts by local and state governments to improve STEM education in their districts and states.[25] The Board is also aware of the difficulty of coordinating many different parties to effect unified change. It is convinced, however, that coordination must occur among all stakeholders in order to ensure long-term improvements in STEM education and bring U.S. students to world-class levels.

Therefore, the Board makes the following two priority recommendations to the Nation. First, ensure coherence in the Nation's STEM education system, and second, ensure that students are taught by well-prepared and highly effective teachers.

The Board feels both recommendations address significant issues and are of equal importance.

Priority Recommendation A: Ensure Coherence in the Nation's STEM Education System

To meet the Nation's demands for a numerate and technologically and scientifically literate workforce, the U.S. needs a nationally coherent STEM education system. Coherence in STEM education means coordination of what, when, and to whom STEM subjects are taught – both horizontally among states and vertically across grade levels from pre-K through the first years of college or vocational school. To ensure this coherence, the Board recommends the nationwide dissemination and implementation of best educational practices based on world-class research and national experience.

The impact of a coherent STEM education system would be widespread. Coordination of STEM content among states and across grade levels would ensure that classes focus on depth of understanding, not just coverage of topics. Thoughtfully sequenced classes would be structured to balance students' acquisition of content knowledge with their development of analytical, critical thinking, and problem-solving skills. They also would foster in students the ability to make connections among ideas and build a capacity for life-long learning.

The Board recommends the following specific actions to achieve coherence in STEM education:

A.1. Actions for Coordination of Key Stakeholders

The Board proposes a new infrastructure and set of activities to provide the necessary coordination among various stakeholders in order to achieve coherence in STEM education. The structural changes recommended in this section will not alone solve all the problems in STEM education. The proposed changes, however, are intended to increase communication and to bring together Federal and non-Federal parties in a forum where meaningful actions can be discussed and implemented. These parties should work together to implement the many excellent recommendations outlined in the Commission's report to the Board and in the many other reports written by expert panels.

The National Council for STEM Education's central responsibilities would be to coordinate and facilitate STEM education initiatives across the Nation, as well as to inform policymakers and the public on the state of STEM education across the United States.

1. The National Council for STEM Education

The Board recommends that Congress pass and the President sign into law an act chartering a new, independent, and non-Federal National Council for STEM Education (Council). The Council's central responsibilities would be to coordinate and facilitate STEM education initiatives across the Nation, as well as to inform policymakers and the public on the state of STEM education across the United States. As part of the Council's charter, Congress should require Federal STEM education programs[26] to be coordinated with state and local education agencies through the Council.

Key local and state governmental agencies and non-governmental organizations would comprise the voting membership of the Council (see Figure 2). Non-voting seats would be reserved for the Federal Government through the National Science and Technology Council (NSTC) of the Office of Science and Technology Policy in the Executive Office of the President and congressional representatives. Congress would specify the representation of the Council's seats in its charter. The Board recommends that Congress appoint the initial

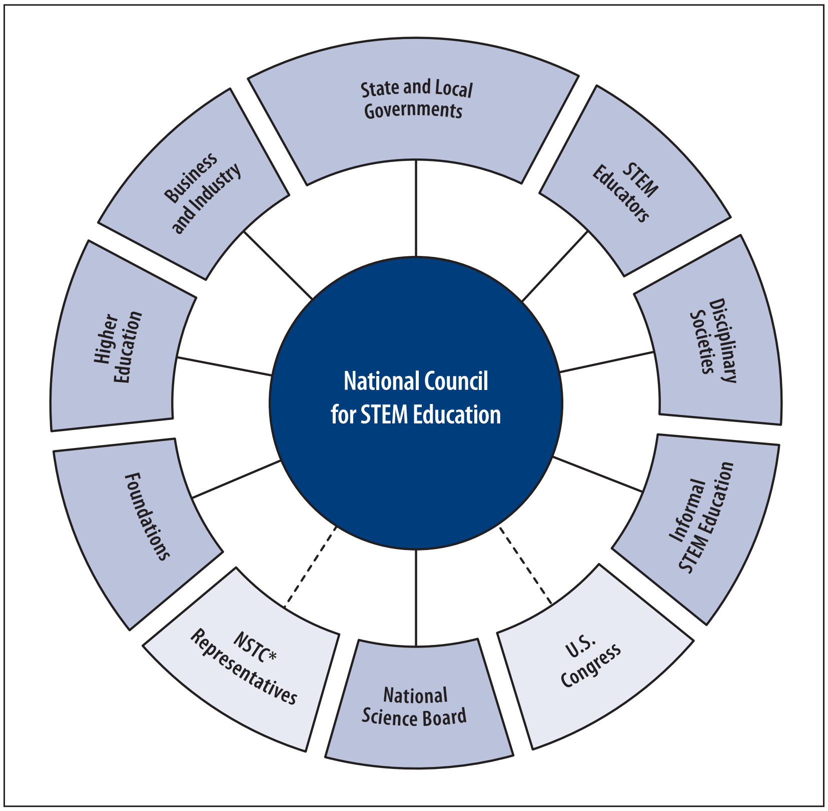


Figure 2. Potential Membership of the National Council for STEM Education

* NSTC refers to the National Science and Technology Council in the President's Office of Science and Technology Policy

members and co-chairs of the Council and that the initial Council members agree upon an orderly process to appoint subsequent members and co-chairs.

The Board recommends that the Council have approximately twenty-five members. Some seats should be permanently allocated to key stakeholder groups of such importance that they should always be represented on the Council. These seats would be filled by two State Governors, two chief state school officers, a representative of a local school board or government, two representatives from higher education, (including one representing community colleges), a practicing STEM classroom teacher, a school administrator, and a representative from the National Science Board.[27] The remaining seats should rotate among stakeholder groups and be filled by members such as STEM educators at all levels, informal STEM educators, and officials from local and state education and governmental organizations, higher education associations, business and industry, private foundations, and STEM disciplinary societies. The Board recommends that the initial co-chairs of the Council be a state governor and a chief state school officer. A list of potential Council members is provided in Appendix A.

The Board suggests that Congress provide funding for an initial period of 5 years for operating expenses (including a small professional staff) to determine the Council's effectiveness (see Appendix B). In the long term, funding for the Council's basic operations and special projects would transition to voluntary contributions from the Council's various stakeholder groups. A successful model for this funding scheme is the Transportation Research Board of the National Academies,[28] where states and other stakeholders have found this body valuable enough to allocate funding to support it.

The core mission of the Council would be to provide guidance as well as to coordinate and facilitate the flow of STEM education information among the various stakeholders.

The core mission of the Council would be to provide guidance as well as to coordinate and facilitate the flow of STEM education information among the various stakeholders. The Council would provide leadership by identifying critical deficiencies in the Nation's STEM education system and proposing strategies for its members to collaborate to address these shortcomings. It would also serve as a primary focal point for Federal agencies to improve their coordination with local and state school systems, per a key recommendation in the report of the Academic Competitiveness Council (ACC).[29] The Council could provide an effective forum for working towards the National Governors Association's goal for states to "identify best practices in STEM education and bring them to scale."[30] In line with this general framework, the Council would:

- Issue a regular report that highlights the status of STEM education in states and the Nation. This could complement the Board's biennial *Science and Engineering Indicators*.
- Evaluate progress toward the goals laid out in this action plan on a regular and sustained basis, including the effectiveness of the NSTC Committee on STEM Education's efforts to coordinate Federal K-12 STEM education programs.
- Serve as a national resource by disseminating to local and state education agencies information on research on teaching and learning, including best educational practices and models for effective STEM teaching and learning, P-16 alignment of STEM education, and scaling up of effective, proven programs.
- Coordinate and assist with the development of national STEM content guidelines for pre-K-12. These would draw on the considerable work already accomplished by various groups and disciplinary societies.
- Work with the Department of Education and the National Assessment Governing Board (NAGB)[31] to ensure that the National Assessment of Educational Progress (NAEP)[32] is aligned with the new STEM content guidelines to be developed.
- Help states establish or strengthen existing P-16 or P-20 councils[33] and serve as a technical resource center for P-16/P-20 councils.
- Work with all stakeholders to address: (a) the removal of barriers that exist throughout the Nation to compensating STEM educators at market rates; and (b) the removal of barriers imposed by school district wage guides on the movement of STEM educators between districts both within and across state borders.
- Work to coordinate the development of national standards for STEM teacher certification.
- Propose models for effective teacher professional development.

The Council might also consider developing programs to:

- Coordinate the development and maintenance of integrated data management systems to consolidate and share information among states on STEM educational practices, research, and outcomes, including, for example, student assessment results, teacher quality measures, and high school graduation requirements;
- Launch and sustain a public education initiative to raise awareness that STEM education is essential for the Nation's success – both domestically and globally;
- Assemble a database of opportunities for teachers interested in summer research in a STEM field in a government research laboratory, institution of higher education, or STEM-related business or industry; and
- Assemble a database of grants and other funding opportunities for STEM classroom resources to be used by teachers and local school districts.

2. Office of Science and Technology Policy – NSTC

The Board recommends that the President's Office of Science and Technology Policy[34] create a standing Committee on STEM Education within the National Science and Technology Council (NSTC)[35] with the responsibility of coordinating STEM education across all Federal agencies. Although the NSTC Committee on Science currently has a Subcommittee on Education and Workforce Development,[36] the critical importance of STEM education to the Nation merits attention at the full committee level. Both the Board's own Commission and the recent Academic Competitiveness Council report[37] from the Secretary of Education recommend that coordination of Federal agencies' STEM education efforts occur through the NSTC. Members of the NSTC Committee on STEM Education would include representatives from all Federal departments and agencies that play a role in STEM education, including the national laboratories. The Board recommends that the co-chairs of the Committee be representatives from the Department of Education and the National Science Foundation.

The Board recommends that the President's Office of Science and Technology Policy create a standing Committee on STEM Education...with the responsibility of coordinating STEM education across all Federal agencies.

The NSTC Committee on STEM Education would:

- Coordinate among all Federal departments and agencies involved in STEM education research and programs to inventory and assess the effectiveness and coherence of Federally funded STEM education programs; and
- Represent all Federal agencies on the National Council for STEM Education and coordinate the STEM education efforts of the Federal agencies with local and state governments through the National Council for STEM Education.

3. The U.S. Department of Education

The Board recognizes the important role of the U.S. Department of Education in STEM education, particularly in providing funding for STEM education programs. Accordingly, the Board recommends that the Secretary of Education consider appointing an expert in STEM education as a new Assistant Secretary of Education or take other measures to ensure the outcomes described below. The office of this new Assistant Secretary could serve two functions. First, it could provide a central planning resource to strengthen existing and future STEM-related programs within the Department. Second, it could be a much-needed point of contact for states and other agencies across the Federal Government in efforts to coordinate the Department's STEM education efforts with all stakeholders through the National Council for STEM Education. As part[38] of fulfilling these functions, the new Assistant Secretary for STEM Education could:

- Focus the Department of Education's efforts to use its funding capabilities to support quality, research-based STEM teacher professional development and to provide technical assistance to support STEM learning;
- Lead an effort for improvement and innovation in STEM-related education research and programs in all offices, bureaus, divisions, and centers within the Department of Education;
- Inform the Secretary of Education, policymakers, and STEM practitioners about the effectiveness of STEM-related education research and programs operated within the Department;
- Ensure that the Department of Education is coordinating with NSF and other agencies and groups to scale up peer-reviewed and research-based STEM education programs that have demonstrated effectiveness; and
- Marshal the resources of the Department of Education to support local and State governments and other stakeholders as they implement the recommendations for coherence in STEM education. Such support could include assistance with developing STEM content guidelines, aligning assessments with national STEM content guidelines, and aligning STEM learning across grade levels.

4. The National Science Foundation

Education is a core mission of the National Science Foundation (NSF), and NSF has exercised an important leadership role in STEM education at all levels for decades. Regarding STEM education at the K-12 level, the Board recommends that NSF focus its activities in three critical, interrelated areas: (1) research on learning and educational practice and the development of instructional materials; (2) development of human capital in STEM fields, including STEM teachers; and (3) improvement of public appreciation for and understanding of STEM (see Figure 3).

A clear framework for the NSF's role in STEM education is essential in order for NSF to set STEM education priorities and determine which activities merit a commitment of its resources. The development and funding of education programs should reflect the NSF's institutional priorities and not occur on a case-by-case basis. The Board believes that:

NSF should develop a clear internal STEM education road map and an overarching set of priorities for its STEM education activities. NSF should report back to the Board with an interim report in early 2008 and a final STEM education road map for Board approval at the Board's May 2008 meeting. The goal of NSF should be to begin implementing these priority activities in FY2009 and fully incorporate the newly articulated STEM education road map priorities into its FY2010 budget request.

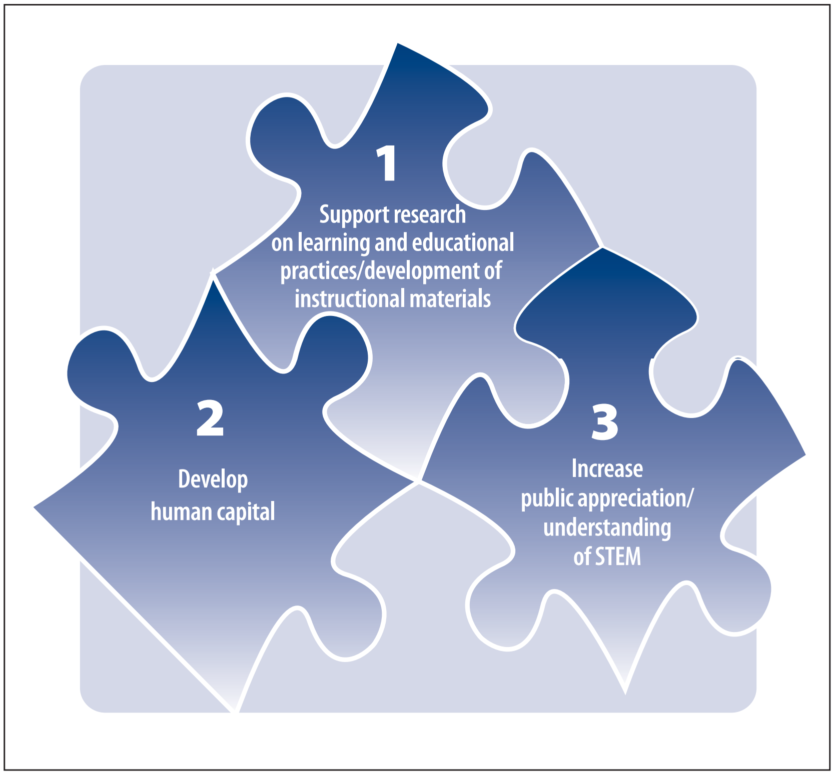


Figure 3. NSF K-12 Education Priorities

The following guidance can be the basis of this road map, which should be developed with the input of the Directorate for Education and Human Resources (EHR) Advisory Committee.

Since P-20 STEM education is a major institutional priority for NSF,[39] efforts to focus NSF's STEM education efforts should be agency-wide and not limited to the EHR Directorate.[40] The internal NSF STEM education road map should promote coherence of goals within the agency by addressing the cross-cutting areas between the EHR and Research and Related Activities (R&RA) Directorates[41] and among the scattered education activities in the R&RA Directorates and include all STEM disciplines within NSF.

Secondly, as NSF develops its institutional STEM priorities and internal STEM education road map, it should recognize that it occupies a unique position among the Federal agencies and within the STEM education community. NSF possesses a profound knowledge base in STEM disciplines, deep involvement with the scientific and engineering research communities, ongoing relationships with institutions of higher education, and a Congressional mandate to be involved in STEM education at all levels. No other Federal agency or organization is so well-situated to make informed contributions to the Nation's P-20 STEM education system, but NSF must be strategic in how it acts. NSF should leverage its assets in partnership with other Federal agencies, institutions of higher education, and the broader STEM education community in order to maximize its impact on P-20 student interest and achievement in STEM disciplines. The NSTC Committee on STEM Education and the National Council for STEM Education will provide contexts for forming and effectively utilizing partnerships; NSF should be an eager and proactive participant alongside other members of these bodies.

The NSF STEM education road map and strategic priorities should reflect the Foundation's responsibilities to:

(1) Support research on learning and educational practices and the development of instructional materials.

Among Federal agencies, NSF has the primary responsibility for research on teaching and learning in STEM disciplines.

Among Federal agencies, NSF has the primary responsibility for research on teaching and learning in STEM disciplines. NSF currently performs many functions in STEM education, ranging from funding basic research on teaching, learning, and teacher education, to supporting applied research on the role and impact of educational innovations, to evaluating the implementation of new programs. NSF also plays a critical role in the development of instructional materials. The Board previously addressed the importance of quality instructional materials in its 1999 report, *Preparing Our Children*.[42]

As NSF is developing a road map for its support of research on learning and educational practices and the development of instructional materials, several issues are critical to consider. These include how educational research areas are identified, how the results of NSF-supported education research are disseminated and made available to guide large-scale implementation efforts, how STEM education programs are evaluated, and how the role of cyberinfrastructure can support STEM education.

First, as NSF sets strategic priorities for its research on learning and educational practices, it should consider the value of projects from both the education research community and the world of practice. While continuing to support research initiated within the education research community and maintaining its longstanding tradition of excellence, NSF should also promote innovation in STEM education by supporting research that responds to critical needs from the field. NSF should ensure that mechanisms are in place to collect input from educators and policymakers on grand challenges from the field and to ensure that its research programs are meeting real-world needs and expectations. In this way, NSF could work to provide solutions and tools for addressing the challenges that teachers face in classrooms every day across the Nation.

Among areas that NSF should consider including as part of its educational research portfolio are:

- Infrastructure that can support large-scale change – such as centers of excellence to research and develop new curricula, effective teaching strategies, and professional development models;
- Programs that systematically study the role of technology and cyber-enabled teaching in facilitating learning; and
- Research on entire education systems, including field research components and the synthesis of research results from the entire field.

In addition to setting its own research priorities, NSF should lead an effort to develop a national road map for research to improve P-20 STEM education. Importantly, NSF should collaborate with the Department of Education and others, including local and state entities, on the identification, development, and dissemination of best practices in STEM education.

Second, a critical challenge NSF must meet is to develop better mechanisms for informing STEM researchers, the STEM education community, and policymakers of the beneficial results flowing from STEM education research and STEM education programs at NSF. NSF should create mechanisms to scale up proven, peer-reviewed, research-based innovations so that they have maximum impact. In addition, in an era when private and corporate foundations are increasing their interest and investments in STEM education programs, NSF should provide a research base for them so that they are able to develop their programs based on proven practices.

Third, in the context of the Academic Competitiveness Council (ACC) report on spending on STEM education programs across Federal agencies and the need for rigorous evaluation of these programs,[43] NSF should build on its base of technical expertise in evaluation to provide assistance to agencies in defining rigorous evaluation criteria and conducting evaluations. While the ACC report identified randomized controlled trials as the strongest study design for determining the effectiveness or impact of educational innovations, educational researchers also recognize as valid other ways to compare innovations with the status quo. Evaluation criteria should include how to determine the effectiveness of programs and their potential impact. In a limited-resource context, criteria for determining which programs should be funded and scaled up must consider not only whether programs do what they are intended to do, but whether the outcome is worthwhile. NSF should provide a research base to guide states and other Federal agencies as they make those decisions. It should also apply this strategic thinking to the evaluation of its own education programs and make use of external evaluators.

Fourth, a specific area in which NSF could make significant contributions is in the development of cyberinfrastructure, including computer gaming and simulations, to bolster STEM teaching and learning.[44] Cyber-enabled technologies could allow:

- The development, collection, distribution, and curation of digital content such as animations, simulations, text, video, data sets, lesson plans, and curricula. (NSF's National Science Digital Library (NSDL)[45] can play a role here, as can other consortial efforts, especially those focused on open source software and open access content);
- Access to virtual laboratory facilities that can bring general and specialized laboratory experiences into nearly any classroom – regardless of geographical location – via the internet;
- Collaborations among STEM students, teachers, researchers, and those designing and developing digital teaching and learning resources;
- Acquisition by students of knowledge and skills essential to success in the technology-rich future; and
- Active engagement of the current, internet-accustomed pre-K-12 student population in STEM.

Finally, NSF should take the lead in nurturing and developing a community of researchers – both social scientists and educational researchers – qualified to perform research on effective educational practices in order to generate the desired research base. NSF should also support those who develop instructional materials and learning resources.

(2) Develop human capital.

NSF can play a significant role in strengthening the STEM teaching force because it has a unique relationship with and ability to effect large-scale change in the higher education system.

NSF should continue to play a critical role in developing human capital in STEM fields. The science and engineering workforce includes pre-college STEM teachers as well as those working in research, industry, and higher education. Developing a strong STEM teaching force would significantly strengthen STEM education across the Nation and bolster the science and engineering workforce. NSF can play a significant role in strengthening the STEM teaching force because it has a unique relationship with and ability to effect large-scale change in the higher education system. NSF should consider support for the following types of programs to strengthen pre-college STEM teaching:

- Develop and fund effective programs for STEM teacher preparation. This could include expansion of the Robert Noyce Scholarship program,[46] which targets college students aspiring to teach STEM at the high school level.
- Use its strong connections with higher education to encourage and provide tools to university faculty and administrators who are committed to providing effective STEM teacher preparation programs.
- Develop programs that encourage student interest in STEM fields at all grade levels. One possibility would be to develop programs that provide STEM experiences for high school students similar to those offered by the Research Experiences for Undergraduates (REU) program.[47]
- Use its research base in learning and educational practice to develop and disseminate effective in-service teacher professional development model programs or modules that can be implemented on the large scale.
- Continue to support and grow programs that build bridges between P-12 and higher education, such as its highly successful model Math and Science Partnership (MSP) Program. The NSF's MSP program has demonstrated success in improving both student mathematics and science performance in K-12 schools and the willingness of higher education STEM faculty to work with K-12 teachers.[48] The Board is on record with its strong support for this program at NSF.[49] Consideration should be given to expanding the program to include technology and engineering partnerships as well as math and science.
- Support STEM professionals who wish to pursue research on teaching and learning in their respective STEM fields, perhaps in collaboration with education researchers with complementary and supporting interests and skills.
- Expand financial support for programs that have an established record of improving the performance and persistence of minority students pursuing STEM careers, including STEM teaching, such as the Louis Stokes Alliance for Minority Participation (LSAMP).[50]
- Partner with secondary schools, institutions of higher education, business and industry, and government agencies to strengthen the technical workforce.
- Ensure that STEM teachers and students are aware of and familiar with the full range of opportunities provided by cyber-enabled teaching, discovery, and learning.

(3) Increase public appreciation for and understanding of science, technology, engineering, and mathematics.

NSF should continue to develop and fund programs that increase public appreciation for and understanding of STEM. NSF should consider how its STEM outreach portfolio can be modified to provide more coherent public outreach on STEM and STEM education issues.

NSF should continue to develop and fund programs that increase public appreciation for and understanding of STEM.

NSF also should consider ways in which it can promote partnerships both within NSF and the broader scientific community to increase public appreciation for and understanding of STEM. Within NSF, collaboration should be encouraged among all NSF directorates and offices, including, in particular, the Office of Legislative and Public Affairs (OLPA), the Directorate for EHR, and the Directorate for Social, Behavioral, and Economic Sciences (SBE), which performs research on effective communication.

As NSF is developing a road map for its public outreach efforts, it should consider directing resources toward several areas. These include:

- STEM programming in broadcast media. Television and movies are both important sources of information for the public on STEM fields;[51]
- Web-based resources and facilities; and
- Museums and informal STEM education learning environments. In the interest of coherence, NSF should make efforts to coordinate the activities of the informal STEM education community with the formal STEM education system. NSF should assist these institutions in developing materials and programs that enhance standard classroom curricula and provide rigorous professional development for teachers.

Furthermore, the Board has previously pointed out the role that the Board itself can play in promoting a public understanding of science and has called for each individual Board Member to become a "'personal ambassador' of fundamental science and engineering."[52] The Board should take on the responsibility not only of promoting public appreciation for and understanding of STEM fields and ground-breaking research in STEM fields, but also of highlighting the absolute importance of P-20 STEM education to the Nation's continued capacity for innovation and global competitiveness.

A.2. Actions for Horizontal Coordination and Coherence

The Board recommends increased coordination of STEM education among states via the actions described below. Although local education agencies and states bear the ultimate responsibility for implementation, the Board puts forth the following recommendations to benefit students in all states.

1. Develop National STEM Content Guidelines

The National Council for STEM Education should facilitate a strategy to define voluntary national STEM content guidelines.[53,54] These guidelines should define the essential knowledge and skills needed at each grade level for each STEM discipline and emphasize critical thinking skills. The effort should consider pre-existing guidelines[55] and strive to be clear, specific, and articulated between each grade level,[56] to incorporate the cumulative development across grade levels and connections between ideas, and to reflect international comparisons. Participants in the guideline development process should include representatives from STEM disciplinary societies, professional STEM teacher organizations, state education agencies, and schools of education. Local education agencies and states should be encouraged to voluntarily align their own STEM content standards to these national guidelines. A model for the development and voluntary adoption of content guidelines is the National Council of Teachers of Mathematics (NCTM) curriculum focal points.[57,58] A further example of a group of states voluntarily adopting mathematics content standards that reflect international comparisons has been successfully facilitated by Achieve, Inc. and its American Diploma Project.[59] STEM content guidelines should allow flexibility for local and state education agencies to choose curricula that best meet local needs in adhering to these guidelines while still promoting very high-quality STEM education.

2. Align the Metrics Used for Assessment of Student Performance with National STEM Content Guidelines

The National Council for STEM Education should work with those who develop and administer assessments to construct consensus-based metrics for assessing student performance that are aligned with the new national STEM content guidelines.[60] International benchmarks should be taken into account in this effort.[61] Once national STEM content guidelines are developed, the National Assessment Governing Board (NAGB) should investigate alignment of the National Assessment of Educational Progress (NAEP) tests utilizing these guidelines.

3. Ensure that Assessments under No Child Left Behind Promote STEM Learning

The Board supports science being considered part of adequate yearly progress (AYP) as defined by No Child Left Behind (NCLB).[62] The Board recommends that NCLB eventually align its expectations of states with the STEM content guidelines discussed above and that states utilize assessments that measure the knowledge, critical-thinking skills, and problem-solving abilities required to meet real-life challenges.

4. Communicate Best Practices

The National Council for STEM Education should serve as a forum for NSF and the Department of Education to gather and review inputs based on research and practical experience and disseminate information on best practices in STEM teaching and learning. The Council should serve as a central reference bank for information about existing research on teaching and learning and models for scaling up effective educational and teacher professional development programs. In order to maximize its effectiveness, the Council should partner with other relevant organizations to disseminate information about best educational practices. For instance, the Council might partner with the National Governors Association (NGA) Center for Best Practices to support the NGA's current initiative to help states establish state Science, Technology, Engineering, and Math Centers.[63] These centers will engage in redesigning K-12 STEM education in order to enhance their states' economies and innovation capacity. Another potential partner might be the NSF's National Science Digital Library.[64]

STEM content guidelines should be designed so that as students move from one grade level to the next, they cumulatively build the foundational skills and knowledge needed to succeed at the next grade level.

A.3. Actions for Vertical Alignment and Coherence

The Board recommends that STEM education be provided to students in a coherent system that is vertically aligned across grade levels from pre-K through the first years of higher education. STEM content guidelines should be designed so that as students move from one

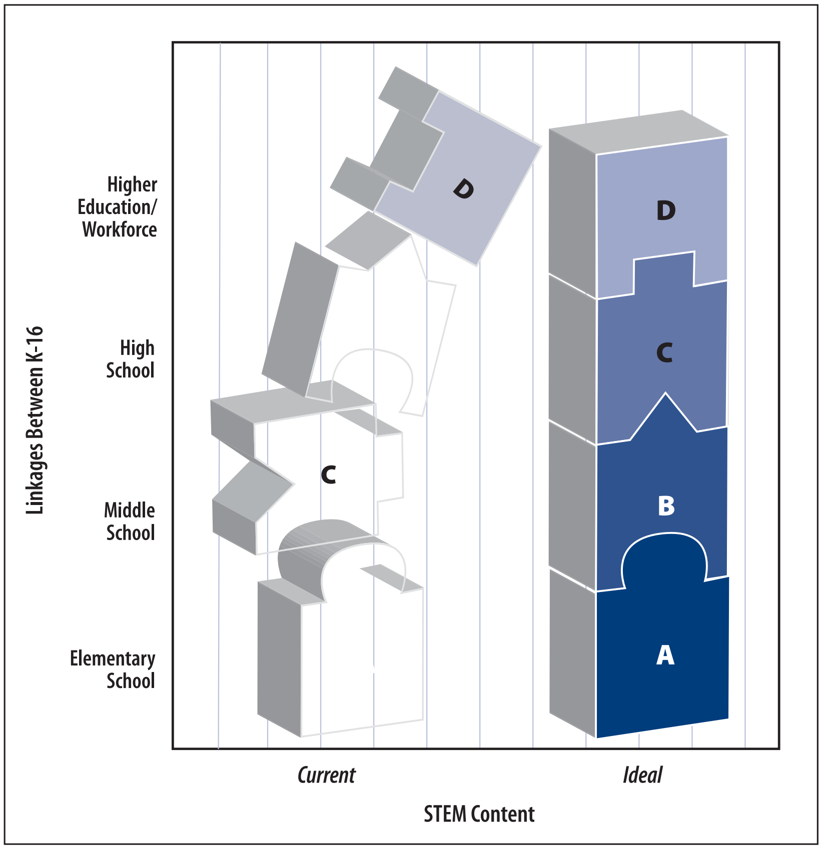


Figure 4. Vertical Integration a Key Component to Successful STEM Learning

Currently STEM learning is not aligned among grade levels, resulting in an unstable foundation in STEM. Ideally, STEM learning should build cumulatively from one educational level to the next.

grade level to the next, they cumulatively build the foundational skills and knowledge needed to succeed at the next grade level (see Figure 4). The Board recommends that the following actions be taken to enhance vertical alignment among all levels of STEM education.

1. Improve the Linkage between High School and Higher Education and/or the Workforce

All stakeholders should make a serious effort to minimize the current disconnect between high school graduation requirements and the skills and knowledge required to succeed in higher education and the workforce. The Board applauds efforts such as those of the American Diploma Project[65] and the National Governors Association Innovation America Initiative to "align state K-12 standards and assessments with postsecondary and workforce expectations for what high school graduates know and can do."[66] Career and technical education centers should be involved in these efforts.

2. Create or Strengthen Existing State P-16/P-20 Councils

The National Council for STEM Education should assist state governors in creating new or strengthening existing non-partisan and independent STEM education-focused P-16 or P-20 councils in every state.[67] In some states, P-16/P-20 councils have already been effective policy vehicles for promoting the alignment of STEM content among K-12 schools, two- and four-year institutions of higher education, and the workforce. Each P-16/P-20 council would encompass the input of the Governor, legislature, state education agency, higher education system (including community colleges), local school boards, teacher associations, business and industry, chamber of commerce, private foundations, economic development initiatives, informal STEM education institutions, civic groups, and other professional organizations. Using the resources of the National Council for STEM Education, each P-16/P-20 council would review the STEM education system in its state and develop a strategy for vertical alignment. Additionally, each council would develop an overall vision and set of measurable goals and timelines for implementation of STEM education reform and alignment in its state. They would also share ideas with the Council based on their experiences in the field.

Priority Recommendation B: Ensure that Students Are Taught by Well-Prepared and Highly Effective STEM Teachers

The Board feels strongly that serious national attention must be focused on attracting, preparing, and retaining qualified and committed teaching candidates.

Although this action plan has, thus far, concentrated on structural suggestions to ensure coherence in the Nation's STEM education system, the Board feels strongly that serious national attention must be focused on attracting, preparing, and retaining qualified and committed teaching candidates. STEM educators should be viewed as a valuable national resource, and the best and the brightest should be encouraged to consider pre-college STEM teaching as a profession.

The specific actions described below are meant to increase the number of STEM teachers entering the profession and ensure that thorough pre-service preparation is provided to STEM teachers. Equally, if not more importantly, however, are actions to support current STEM teachers so that they are able to be effective and are more likely to continue in the profession.[68] STEM educators should be provided with adequate mentoring during the critical first few years in the classroom,[69] proper instructional leadership and support while in the classroom, and opportunities for professional growth and enrichment of knowledge and skills. They also should have access to classroom resources that are required for effective STEM teaching and learning, including, for example, textbooks, supplies and equipment for laboratory and/or field experiences, and technology resources.

B.1. Actions for Increasing the Number of Well-Prepared and Highly Effective STEM Teachers in the Classroom

All possible promising strategies for increasing the number of well-prepared and highly effective STEM teachers should be utilized. All STEM stakeholders should work to increase the number of educators who acquire STEM training and the number of STEM-trained professionals who choose pre-college teaching as an occupation. Strategies include augmenting or increasing STEM teacher compensation for highly effective STEM teachers, lowering the barriers for the movement of STEM teachers from one school district or state to another, and providing incentives for the acquisition of STEM content knowledge by those who either aspire to become STEM teachers or are already pre-college teachers in other fields.

The Board recommends that the following actions be taken in order to increase the number of well-prepared and highly effective STEM teachers:

1. Provide Resources to Increase STEM Teacher Compensation

The Board is cognizant that teacher salaries are set and provided by local education agencies; however, local education agencies should be able to offer STEM teachers compensation more closely aligned with that available in other economic sectors.[70] Unless this issue is addressed, it will remain difficult to recruit an adequate number of qualified STEM teachers, particularly at the middle and secondary school levels. Stakeholders should work within the National Council for STEM Education to develop strategies for eliminating the barriers preventing local education agencies and states from increasing STEM teacher compensation. Beyond direct salary increases, stakeholders could consider incentives such as state or Federal tax credits for STEM teachers; pay supplements for increased student performance; pay supplements for obtaining specialized STEM teaching certifications that enhance teaching effectiveness; and augmentation of STEM teacher annual income through summer teacher professional development programs, research experiences, or applied STEM experiences.

2. Provide Resources for Future STEM Teacher Preparation

The National Council for STEM Education, in partnership with the Department of Education and NSF, should coordinate and disseminate information on models to attract and support talented students interested in STEM teaching careers. For example, the Council could promote the expansion of tuition and/or financial assistance programs for college students majoring in STEM content areas who commit to post-graduation careers in teaching. These students could complete a dual enrollment program enabling them to become certified STEM teachers with both content and pedagogy knowledge.[71] Similarly, the Department of Education, NSF, states, and other stakeholders could expand programs that provide loan forgiveness to students majoring in STEM content areas in return for service in teaching.[72]

3. Create and Endorse National STEM Teacher Certification Guidelines

The National Council for STEM Education should coordinate among its members – particularly state teacher credentialing agencies – to develop a mechanism to create and endorse national, rigorous STEM teacher certification guidelines for states to adopt voluntarily. These guidelines would facilitate a teacher's ability to continue teaching when they move from one district or state to another, and they would clarify the requirements for bringing STEM professionals from other occupations into pre-college teaching. Unlike the current National Board Certification program,[73] the goal would not be to reward master teachers, but instead to expand the pool of potential STEM teachers, increase teacher mobility, and increase standards for all STEM teachers. The development of secondary school teacher certification guidelines in sub-specialties is also encouraged.

B.2. Actions for Improving the Quality of STEM Teacher Preparation

All stakeholders and, in particular, teacher education programs at institutions of higher education, should make efforts to ensure that teachers are adequately prepared to teach STEM content. STEM teachers should receive, at a minimum, STEM content knowledge that is aligned with what they are expected to teach. Appropriate STEM content knowledge should be provided to elementary as well as secondary teachers. Although not emphasized here, ensuring that teachers remain current in STEM knowledge and pedagogy is a critical need. Public universities through their outreach efforts, STEM disciplinary societies, national laboratories, and informal STEM education institutions should make efforts to address this need in collaboration with local and state education agencies.

STEM teachers should receive, at a minimum, STEM content knowledge that is aligned with what they are expected to teach.

1. Coordinate STEM Teacher Preparation with National Content Guidelines[74]

Teacher education programs at institutions of higher education should prepare their students to teach curricula aligned with national STEM content guidelines. The National Council for STEM Education, the Department of Education, NSF, higher education accrediting bodies, and teacher certification/licensure bodies should encourage institutions of higher education to ensure that their graduates are adequately prepared with STEM content knowledge, knowledge about how to teach STEM content in laboratory as well as traditional classrooms, and general teaching skills[75] prior to entering the classroom. Thorough preparation of STEM teachers should involve collaboration between the colleges of education and the colleges of arts and sciences and engineering to ensure that STEM content knowledge is acquired at sufficient depth to be useful in their future roles as teachers. STEM university faculty must take ownership and responsibility for the preparation of pre-college teachers by modifying their own teaching to engage and nurture these students. The STEM content knowledge acquired by future STEM teachers should be aligned with the knowledge and skills that their own students will need to succeed in college-level science and engineering courses and the workforce. Disciplinary societies, informal STEM education institutions, and national laboratories all provide STEM content expertise that could be effectively utilized to improve STEM teacher preparation.

2. Improve Articulation Agreements among Institutions of Higher Education

Institutions of higher education should make efforts to improve student and course transfer (articulation) agreements[76] so that students preparing to teach in STEM areas will not be slowed in earning degrees because course credits do not transfer between institutions.

Conclusion

Strengthening STEM education across the Nation is critical to maintaining a high quality of life for our citizens and ensuring that Americans remain competitive in international science and technology. Public awareness and action are critical to addressing this crisis. Jobs in the 21st century, even those outside STEM fields, will increasingly demand a technologically literate workforce. All citizens must have basic STEM literacy in order to be full and active participants in our increasingly technology-based democracy. If STEM education reform is not considered seriously now, the Nation is in danger of failing current and future generations. The recommendations in this action plan are essential to providing the Nation with a population that is numerate and scientifically and technologically literate. The recommendations that we have provided will ensure that all students have the skills and knowledge base to function successfully in our knowledge-based global economy. From this pool of students, some will become critically needed scientists, engineers, mathematicians, and STEM teachers. Ensuring that our education system will produce the next generation of brilliant innovators will require further action, and the Board will pursue this issue subsequently. The Nation must act now to address the critical needs of its science, technology, engineering, and mathematics education system; moving forward with the action plan presented here by the National Science Board should be the first step in launching this effort.

Endnotes

[1] The National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, DC: National Academies Press, 2005). *http://www.nap.edu/execsumm_pdf/11463.pdf*

[2] The House Committee on Appropriations report that accompanied the FY2006 Science, State, Justice, Commerce and Related Agencies Appropriations Bill, included report language endorsing the establishment of the STEM Commission. The report states, "The Committee understands that the Board has taken steps to establish a commission to make recommendations for NSF and Federal Government action to achieve measurable improvements in the nation's science education at all levels. The Committee strongly endorses this effort." This report language was adopted in the final conference report for the Bill. Conference Committee, *Conference Report; Making Appropriations for Science, the Departments of State, Justice, and Commerce, and Related Agencies for the Fiscal Year Ending September 30, 2006, and for Other Purposes*, 109th Cong., 1st sess., 2005, H. Rep. 272, 184.

[3] National Science Board hearings on STEM education were held in December 2005 in Washington, DC, February 2006 in Boulder, CO, and March 2006 in Los Angeles, CA. Transcripts and video from these hearings are available at *www.nsf.gov/nsb*.

[4] See, for example, the argument made by Vannevar Bush in *Science – The Endless Frontier: A Report to the President*, (Washington, DC: U.S. Government Printing Office, 1945). *http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm*

[5] The U.S. Commission on National Security/21st Century stated in its February 2001 Phase III Report that "In this Commission's view, the inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine." The United States Commission on National Security/21st Century, *Roadmap for National Security: Imperative for Change*, (Washington, DC: U.S. Commission on National Security/21st Century, February 15, 2001). *http://govinfo.library.unt.edu/nssg/PhaseIIIFR.pdf*

[6] The National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, (Washington, DC: National Academies Press, 2005). *http://www.nap.edu/execsumm_pdf/11463.pdf*

[7] National Center for Education Statistics, *Remedial Education at Degree Granting Postsecondary Institutions in Fall 2000*, (Boston, MA: National Center for Education Statistics, 2000). *http://nces.ed.gov/pubs2004/2004010.pdf*

[8] The Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) test emphasizes "students' ability to apply scientific and mathematical concepts and thinking skills to problems they may encounter, particularly in situations outside the classroom." In 2003, 20 out of 31 countries scored higher than the United States among 4th graders, 8th graders, and 15 year olds. National Science Foundation, Division of Science Resource Statistics, *Science and Engineering Indicators 2006*, (Arlington, VA: National Science Foundation, February, 2006) *http://www.nsf.gov/statistics/seind06/c1/tt01-05.htm*

[9] "As textbooks have to cover more and more topics, keywords and the like, they end up jumping from subject to subject, covering little material in depth." Thomas B. Fordham Institute Report, *The Mad, Mad World of Textbook Adoption*, (Washington, DC: The Thomas B. Fordham Institute, 2004). *http://www.edexcellence.net/doc/Mad%20World_Test2.pdf*

[10] The 2004 Annual Social and Economic Supplement to the U.S. Census found that 15 to 20 percent of school-aged children moved in the previous year." Bureau of the Census of the Bureau of Labor Statistics, *Current Population Survey, 2004 Annual Social and Economic Supplement*, (Washington DC: Bureau of the Census, 2004). *http://www.census.gov/apsd/techdoc/cps/cpsmar04.pdf*. According to a study conducted in 1994 by the U.S. General Accounting Office, one out of six children had attended three or more schools by the end of the 3rd grade. U.S. General Accounting Office, *Elementary School Children Many Change Schools Frequently Harming Their Education*, (Washington DC: General Accounting Office, 1994). *http://archive.gao.gov/t2pbat4/150724.pdf*

[11] National Center for Education Statistics, *Mapping 2005 State Proficiency Standards Onto the NAEP Scales*, (Washington DC: U.S. Department of Education, 2007) *http://nces.ed.gov/nationsreportcard/pdf/studies/2007482.pdf*

[12] National Center for Education Statistics, *Remedial Education at Degree Granting Postsecondary Institutions in Fall 2000*, (Boston, MA: National Center for Education Statistics, 2000). *http://nces.ed.gov/pubs2004/2004010.pdf*

[13] "One-third of our high school graduates are not prepared to enter postsecondary education or the workforce." Council of Chief State School Officers, *Mathematics and Science Education Task Force. Report and Recommendations*, (Washington, DC: Council of Chief State School Officers, November, 2006). *http://www.ccsso.org/content/pdfs/Math%20Science%20Recom%20FINAL%20lowrez.pdf*

[14] The National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation*, (Jessup, MD: Education Publications Center, September 27, 2000). *http://www.ed.gov/inits/Math/glenn/report.pdf*

[15] Levine, Arthur, *Educating School Teachers*, (Washington, DC: The Education Schools Project, September, 2006). *http://www.edschools.org/pdf/Educating_Teachers_Report.pdf*

[16] For example, according to UNC system President Erskine Bowles "...in the past four years, our 15 schools of education at the University of North Carolina turned out a grand total of three physics teachers." Bowles, Erskine. "Inaugural Address." Inaugural address, UNC Presidential Inauguration, Greensboro, NC, April 12, 2006. Note: the number of teachers graduating from the UNC system with a broader science certification was much larger.

[17] In 2003 the median annual (school-year) salary of full-time high school mathematics and science teachers was $43,000 compared to a median annual salary of $72,000 for computer systems analysts, $61,000 for accountants, auditors, and other financial specialists, or $75,000 for engineers. National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates.

[18] The lockstep salary model is a form of determining teacher pay and is used in most public school systems within the United States. In general, this system has a series of pay ladders that are usually based on education levels, teacher certification, and seniority. Each year, a teacher's raise is determined based on the ladder they qualify for within the schedule.

[19] This has been noted before by the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies' *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* as well as in The Center for Teaching Quality's *Performance Pay for Teachers: Designing a System that Students Deserve*. (Hillsborough, NC: Center for Teaching Quality, 2007). *http://www.teacherleaders.org/teachersolutions/TSreport.pdf*

[20] "There are more than 91,000 public schools in the United States governed by 15,000 school districts in 50 states and the extra-state jurisdictions." National Forum on Education Statistics. *The Forum Voice: Spring 2002 (Volume 5, No. 1)*. (Washington, DC: National Forum on Education Statistics, 2002). *http://nces.ed.gov/forum/v_spring_02.asp*

[21] Federal agencies and departments with involvement in elementary and secondary STEM education include, but are not limited to: Department of Education (DoED), National Science Foundation (NSF), Office of Science and Technology Policy (OSTP), Department of Energy (DoE), National Aeronautics and Space Administration (NASA), National Oceanographic and Atmospheric Administration (NOAA), Department of Defense (DoD), National Institute of Standards (NIST), Department of Agriculture (USDA), National Institutes of Health (NIH), Smithsonian Institution, and the United States Geological Survey (USGS). The U.S. Department of Education's *Report of the Academic Competitiveness Council* inventories all Federal STEM education programs. U.S. Department of Education, *Report of the Academic Competitiveness Council* (Washington, DC: U.S. Department of Education, May, 2007). *http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf*

[22] One of the National Science and Technology Council's roles is to coordinate these stakeholders. However, as a cabinet-level Council in the Executive Office of the President, the NSTC's mission and focus varies according to the policy goals of the sitting Administration.

[23] The Space Race began in 1957 with the launch of Sputnik by the Soviet Union. Over the course of the next 12 years, the U.S. and Soviet Union competed to be the first country to conquer outer space. To achieve this, great emphasis was placed on scientific and mathematical skills. To meet this skills need, Congress passed the National Defense Education Act (NDEA) in 1958. The aim of this legislation was primarily to stimulate the advancement of education in the elementary and secondary levels in science, mathematics, and modern foreign languages, but it has also provided aid in other areas, including technical education, and English as a second language. Although the effects of this law are difficult to prove as a result of poor record keeping, the number of bachelor degrees awarded in education rose more sharply than in other fields following the law's passage. It can be said that in the first few years of operation, NDEA had a considerable influence on the growth of graduate education in a number of states which had produced no doctoral graduates or very few up to that time.

[24] In 1975, Congress passed the Education for All Handicapped Children Act (EHA), which required all public schools accepting Federal funds to provide equal access to education for children with physical and mental disabilities. Public schools were required to evaluate handicapped students and create an educational plan with parent input that would emulate as closely as possible the educational experience of non-disabled students. For more information visit: *http://www.scn.org/~bk269/94-142.html*

[25] Although the Board is focusing this report toward public education, it is cognizant that a portion of U.S. students are in private schools (about 10 percent of elementary and high school students in the 2003-2004 school year, according to the National Center for Education Statistics) or are home schooled (2.2 percent in 2003, according to the same source). Broughman, S.P. and Swaim, N.L., *Characteristics of Private Schools in the United States: Results from the 2003-2004 Private School Universe Survey*, (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 2006). *http://nces.ed.gov/pubs2006/2006319.pdf* and Princiotta, D. and Bielick, S. *Homeschooling in the United States: 2003*, (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 2005). *http://nces.ed.gov/pubs2006/2006042.pdf*

[26] According to the GAO's report on Higher Education Federal Science, Technology, Engineering and Mathematics Programs and Related Trends, 13 civilian agencies reported spending about $2.8 billion in Fiscal Year 2004 for 207 education programs. United States Government Accountability Office. *Higher Education Federal Science, Technology, Engineering and Mathematics Programs and Related Trends*. (Washington, DC: U.S. Government Accountability Office, October 2005). *http://www.gao.gov/new.items/d06114.pdf*. It has also been noted in the U.S. Department of Education's Report of the Academic Competitiveness Council that there are 105 STEM education programs across 13 Federal agencies, which have spent approximately $3.12 billion in total funding for Fiscal Year 2006. U.S. Department of Education, *Report of the Academic Competitiveness Council*, (Washington, DC: U.S.

Department of Education, May, 2007). *http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf.*

[27] National Science Board representation on the Council is intended to demonstrate the Board's commitment to long-term, continued engagement with and support of P-16 STEM education.

[28] For example, the National Cooperative Highway Research Program (which is part of the Transportation Research Board) is funded by the state departments of transportation. Support is voluntary and funds are drawn from the states' Federal-Aid Highway apportionment of State Planning and Research (SPR) funds. Furthermore, the funds can be spent only for the administration of problems approved by at least two-thirds of the states. Each state's allocation amounts to 5 and 1/2 percent of its SPR apportionment. More information can be found at: *http://www.trb.org/default.asp*

[29] A similar recommendation was also made in the U.S. Department of Education, *Report of the Academic Competitiveness Council*, (Washington, DC: U.S. Department of Education, May, 2007). *http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf.* In the report they recommend that "Federal agencies should improve the coordination of their K-12 STEM education programs with states and local school systems."

[30] Recommended in the National Governors Association and Council on Competitiveness, *Innovation America: A Partnership*, (Washington, DC: National Governors Association, February 24, 2007). *http://www.nga.org/Files/pdf/0702INNOVATIONPARTNERSHIP.PDF*

[31] The National Assessment Governing Board (NAGB), appointed by the Secretary of Education but independent of the Department, sets policy for the National Assessment Education Program (NAEP) and is responsible for developing the framework and test specifications that serve as the blueprint for the assessments. NAGB is a bipartisan group whose members include governors, state legislators, local and state school officials, educators, business representatives, and members of the general public. Congress created the 26-member Governing Board in 1988. More information can be found on their website: *http://www.nagb.org/*

[32] The National Assessment of Educational Progress (NAEP), also known as "the Nation's Report Card," is the only nationally representative and continuing assessment of what America's students know and can do in various subject areas. More information can be found on their website: *http://nces.ed.gov/nationsreportcard/about/*

[33] P-16 and P-20 Councils are bodies of education stakeholders at the state level including state and local policy makers, teachers, administrators, and parents designed to improve education and to address issues in its educational system.

[34] Congress established the Office of Science and Technology Policy (OSTP) in 1976 with a broad mandate to advise the President and others within the Executive Office of the President on the effects of science and technology on domestic and international affairs. Its primary charge is to serve as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government. More information can be found at *http://ostp.gov/index.html*

[35] The National Science and Technology Council (NSTC) was established by Executive Order in 1993. This Cabinet-level Council is the principal means within the executive branch to coordinate science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of NSTC is the establishment of clear national goals for Federal science and technology investments in a broad array of areas. The Council prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of NSTC is organized under four primary

committees: Science, Technology, Environment and Natural Resources, and Homeland and National Security. More information can be found at: *http://www.ostp.gov/nstc/index.html.*

[36]The National Science and Technology Council Committee (NSTC) on Science Subcommittee on Education and Workforce has, for example, issued relevant reports such as a *Review and Appraisal of the Federal Investment in STEM Education Research*, (Washington, DC: Office of the President, October 2006). *http://www.ostp.gov/nstc/html/ReviewAppraisaloftheFederalInvestmentSTEMEducationResearchOctober06.pdf*

[37] Also recommended in the U.S. Department of Education *Report of the Academic Competitiveness Council*, (Washington, DC: U.S. Department of Education, May 2007). *http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf*

[38] This position could also potentially play an important role in developing programs for the next generation of innovators, the subject of a future National Science Board activity on STEM education.

[39] Although STEM education from pre-kindergarten through graduate education (P-20) is a priority for NSF, this Board action plan is focused on alignment of P-16 STEM teaching and learning and does not consider graduate education.

[40] The NSF Education and Human Resources Directorate is charged with achieving excellence in U.S. science, technology, engineering and mathematics (STEM) education at all levels and in all settings (both formal and informal) in order to support the development of a diverse and well-prepared workforce of scientists, technicians, engineers, mathematicians, and educators and a well-informed citizenry that have access to the ideas and tools of science and engineering. More information can be found at: *http://www.nsf.gov/ehr/about.jsp*

[41] The NSF Research and Related Activities Directorate is the overarching directorate within NSF that is involved in all research and development aspects and which receives funding from Congress to engage in research activities for all non-educational and non-training related programs.

[42] National Science Board, *Preparing Our Children: Math and Science Education in the National Interest*, (Arlington, VA: National Science Foundation, 1999). *http://www.nsf.gov/pubs/1999/nsb9931/nsb9931.pdf*

[43] See Recommendation 2 of the *Report of the Academic Competitiveness Council* which states that, "Agencies and the Federal government at large should foster knowledge of effective practices through improved evaluation and-or implementation of proven-effective, research-based instructional materials and methods." U.S. Department of Education. R*eport of the Academic Competitive Council*. (Jessup, MD: Education Publication Center, May 2007). *http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf*

[44] See also *Cyberinfrastructure Vision for 21st Century Discovery* (Arlington, VA: National Science Foundation, February 2007). *http://www.nsf.gov/pubs/2007/nsf0728/index.jsp*

[45] To access the National Science Digital Library visit *http://nsdl.org/*

[46] The Robert Noyce Scholarship program seeks to encourage talented science, technology, engineering, and mathematics majors and professionals to become K-12 mathematics and science teachers. The program provides funds to institutions of higher education to support scholarships, stipends, and programs for students who commit to teaching in high-need K-12 school districts. More information can be found by visiting: *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5733*

[47]The Research Experience for Undergraduates (REU) program supports active research participation by undergraduate students in any of the areas of research funded by the National Science Foundation.

REU projects involve students in meaningful ways in ongoing research programs or in research projects specifically designed for the REU program. More information can be found by visiting: *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517&org=NSF*

[48] Data gathered through a variety of sources, including a specially developed online management information system, have shown a number of significant improvements, including a rise in proficiency test scores in mathematics and science for students in the partnerships in 2002-2003, 2003-2004, and 2004-2005, as well as other measures. For more information read the National Science Foundation's *Math and Science Partnership National Impact Report* by visiting: *http://www.nsf.gov/news/newsmedia/msp_impact/final_msp_impact_report.pdf*

[49] National Science Board, *A Statement of the National Science Board: In Support of the Math and Science Partnership Program at the National Science Foundation*, (Arlington, VA: National Science Board, 2004). *http://www.nsf.gov/nsb/documents/2004/nsb_msp_statement2.pdf*. More information on the Math and Science Partnership Program can be found at *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5756 and http://hub.mspnet.org/index.cfm.*

[50] The Louis Stokes Alliances for Minority Participation Program (LSAMP) is aimed at increasing the quality and quantity of students successfully completing STEM baccalaureate degree programs, and increasing the number of students interested in, academically qualified for, and matriculated into programs of graduate study. LSAMP supports sustained and comprehensive approaches that facilitate achievement of the long-term goal of increasing the number of students who earn doctorates in STEM fields, particularly those from populations underrepresented in STEM fields. The program goals are accomplished through the formation of alliances. More information can be found at: *http://www.nsf.gov/pubs/2003/nsf03520/nsf03520.htm*

[51] According to the 2006 Science & Technology Public Attitudes and Understanding Indicators, most adults in the U.S. and other countries pick up information about science and technology primarily from watching television, including educational and nonfiction programs, newscasts and newsmagazines, and even entertainment programs. In addition, the internet is also playing a role in communicating science and technology news as the internet moved in 2004 to the second most popular source of news about science and technology. National Science Foundation, Division of Science Resource Statistics, *Science and Engineering Indicators 2006*, (Arlington, VA: National Science Foundation, February 2006). *http://www.nsf.gov/statistics/seind06/c7/c7h.htm*

[52] National Science Board, *Communicating Science and Technology in the Public Interest*, (Arlington, VA: National Science Board, August 3, 2000). *http://www.nsf.gov/nsb/documents/2000/nsb0099/nsb0099.htm*

[53] "Content guidelines" are defined here to mean descriptions of expected student knowledge in various subject areas.

[54] Several pieces of legislation from the 110th Congress include provisions to create STEM content standards. They include the following: H.R. 35, the *Science Accountability Act of 2007*, requires states to establish challenging academic content and student achievement standards in science. S. 164, the *SUCCESS Act*, requires the National Assessment of Educational Progress(NAEP) Board's national academic content and student achievement standards to be competitive with rigorous international standards and set at a level that prepares students for non-remedial higher education, participation in the 21st century workforce, and the Armed Forces. The NAEP Board would be required to provide assistance to any state that works to align its standards with those of the Board. S. 757, the *National Mathematics and Science Consistency Act*, directs the Secretary of Education to work with the National Academy of Sciences to convene a panel to develop voluntary national expectations for science and math education for grades K-12 (the expectations are required to reflect core ideas in math and science education which are common to all states). Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/* (accessed April 19, 2007).

[55] These grade-specific standards should build upon pre-existing standards such as: National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics*, (Reston, VA: NCTM, 2000); International Technology Education Association, *Standards for Technological Literacy* (Reston, VA: ITEA, 2000). *http://standards.nctm.org/*; American Association for the Advancement of Science, Benchmarks for Science Literacy (New York: Oxford University Press, 1993). *http://www.project2061.org/publications/bsl/online/bolintro.htm*; National Research Council, *National Science Education Standards* (Washington, DC: National Academy Press, 1996); and Douglas Gorham, Pam Newberry, and Theodore Bickart, "Engineering Accreditation and Standards for Technological Literacy," *Journal of Engineering Education* 92 (Ashburn, VA: American Society for Engineering Education, 2003).

[56] The Third International Mathematics and Science Study (TIMSS) observed that mathematics and science curricula in U.S. high schools lack coherence, depth, and continuity and cover too many topics in a superficial way. Standards must emphasize depth of understanding over exhaustive coverage of content. National Center for Education Statistics, "Third International Mathematics and Science Study," *Institute of Education Sciences*, (Washington, DC: U.S. Department of Education, 2003). *http://nces.ed.gov/timss/index.asp*

[57] National Council of Teachers of Mathematics, *Curriculum Focal Points: From Pre-Kindergarten through Grade 8 Mathematics*, (Reston, VA: National Council of Teachers of Mathematics, 2006). *http://www.nctmmedia.org/cfp/front_matter.pdf*

[58] Although several individuals highlighted the important contributions made by the AAAS Project 2061 *Benchmarks for Science Literacy* (*http://www.project2061.org/publications/bsl/*) and *Atlas of Science Literacy* (*http://www.project2061.org/publications/atlas/default.htm*) during the public comment period, the benchmarks need to be updated as they are now more than a decade old and are grade-span rather than grade-specific.

[59] "Created by the nation's governors and business leaders in 1996, Achieve, Inc., is a bipartisan, non-profit organization that helps states raise academic standards, improve assessments and strengthen accountability to prepare all young people for postsecondary education, work, and citizenship. Achieve has helped more than half the states benchmark their academic standards, tests, and accountability systems against the best examples in the U.S. and around the world. It has developed benchmark standards that describe the specific math and English skills high school graduates must have if they are to succeed in postsecondary education and high-performance jobs. Achieve works with states to incorporate these expectations in state standards and assessments for high schools. Achieve has also developed grade-level math standards for kindergarten through grade 8." *http://www.achieve.org/*

[60] Also recommended in the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995*, (Arlington, VA: National Science Foundation, 1983); The National Science Board, *America's Pressing Challenge - Building a Stronger Foundation: A Companion to Science and Engineering Indicators*, (Washington DC: Government Printing Office, 2006). *http://www.nsf.gov/statistics/nsb0602/nsb0602.pdf*; and the Domestic Policy Council of the Office of Science and Technology Policy. *America's Competitiveness Initiative; Leading the World in Innovation*, (Washington DC: Government Printing Office, 2006). *http://www.whitehouse.gov/stateoftheunion/2006/aci/aci06-booklet.pdf*

[61] As part of the National Governors Association (NGA) Innovation America initiative, funding for voluntary international benchmarking has been proposed and included as part of the STEM Center Grant Program. As part of this program, the NGA has encouraged states to participate in international assessments and align their standards and assessments with international benchmarks. More information can be found by visiting: *http://www.nga.org/portal/site/nga/menuitem.751b186f65e10b568a278110501010a0/*

?vgnextoid=e34e2bad2b6dd010VgnVCM1000001a01010aRCRD&vgnextchannel=92ebc7df618a2010VgnVCM1000001a01010aRCRD

[62] Using such metrics as an added measure of AYP is reflected in H.R. 35, the *Science Accountability Act of 2007*. This act would amend the Elementary and Secondary Education Act of 1965 to require the use of science assessments in the calculation of adequate yearly progress. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/* (accessed April 19, 2007).

[63] The STEM Center Grant Program is part of National Governors Association (NGA) Innovation American initiative. The grant program was designed to build off the success of the High School Honor States initiative. STEM centers will help state K-12 education systems ensure all students graduate from high school with essential competencies in STEM subjects. More information on the program can be found by visiting: *http://www.nga.org/Files/pdf/0702INNOVATIONSTEMRFP.PDF*

[64] To access the National Science Digital Library, visit *http://nsdl.org/*.

[65] The American Diploma Project (ADP) is a partnership of four national organizations (Achieve, The Education Trust, the National Alliance of Business, and the Fordham Foundation) and five states (Indiana, Kentucky, Massachusetts, Nevada, and Texas) that joined forces in a collaborative effort to strengthen ongoing standards-based reform efforts at the state level. Its goal is to ensure that American high school students have the knowledge and skills necessary for success following graduation, whether in college, the workplace or the armed services. The ADP also aims to develop and solidify demand for standards-based high school assessment data in admissions and hiring processes; assist states in revising and/or strengthening their current standards-based systems; and develop national high school graduation benchmarks in English language arts and mathematics that all states may use to calibrate the quality and rigor of their standards and assessments. More information can be found by going to: *http://www.achieve.org/node/604*

[66] National Governors Association and Council on Competitiveness, *Innovation America: A Partnership*, (Washington, DC: National Governors Association, February 24, 2007). *http://www.nga.org/Files/pdf/0702INNOVATIONPARTNERSHIP.PDF*

[67] Also recommended in Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education*, (Washington, DC: Business-Higher Education Forum, January 2005). *http://www.bhef.com/solutions/MathEduPamphlet_press.pdf*; National Science Board, *America's Pressing Challenge – Building a Stronger Foundation*, Companion to *Science and Engineering Indicators 2006*, (Arlington, VA: National Science Foundation, 2006). *http://www.nsf.gov/statistics/nsb0602/*; National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995*, (Arlington, VA: National Science Foundation, 1983); Domestic Policy Council of the Office of Science and Technology Policy *America's Competitiveness Initiative; Leading the World in Innovation* (Washington DC: Government Printing Office, 2006). *http://www.whitehouse.gov/stateoftheunion/2006/aci/aci06-booklet.pdf*; National Science Board, *Preparing Our Children: Math and Science Education in the National Interest*, (Arlington, VA: National Science Foundation, 1999). *http://www.nsf.gov/pubs/1999/nsb9931/nsb9931.pdf* ; American Association for the Advancement of Science, *A System of Solutions: Every School, Every Student* (Washington, DC: American Association for the Advancement of Science, 2005). *http://ehrweb.aaas.org/PDF/GEReport.pdf*

[68] Based on data compiled from the Teacher Followup Survey, about half of all teachers who depart their jobs give as a reason either job dissatisfaction or the desire to pursue another job, in or out of education. Notably, math/science teachers are significantly more likely to move from or leave their teaching jobs because of job dissatisfaction than are other teachers (40 percent of math/science and 29 percent of all teachers). Of those who depart because of job dissatisfaction, the most common

reasons given by math and science teachers are: low salaries (56.7%); a lack of support from the administration (45.9%); student discipline problems (29%); and a lack of student motivation (21.4%). Note that the percent of teachers giving various reasons for turnover each add up to more than 100 percent, because respondents could indicate up to three reasons for their departures. Ingersoll, R. *Turnover Among Math and Science Teachers in the U.S.* (Washington, DC: Department of Education, 2000).
www.ed.gov/inits/Math/glenn/Ingersollp.doc

[69] According to data compiled by the National Center for Education Statistics as part of their Schools and Staffing Survey and the Teacher Followup Survey (TFS), 11 percent of teachers will leave the teaching profession altogether after only one year of teaching; 29 percent will leave after 3 years, and a full 39 percent will have left after 5 years. Data is based on surveys conducted during 1987-89; 1990-92; and 1993-95. Ingersoll, R. *Turnover Among Math and Science Teachers in the U.S.* (Washington, DC: Department of Education/National Commission on Mathematics and Science Teaching for the 21st Century, 2000). *www.ed.gov/inits/Math/glenn/Ingersollp.doc*

[70] "To make precollege science and math teaching more competitive with other career opportunities, resources must be provided to compensate teachers of mathematics, science, and technology comparably to similarly trained S&E professionals in other economic sectors." National Science Board, *America's Pressing Challenge: Building a Stronger Foundation*, (Arlington, VA: National Science Foundation, February, 2006). *http://www.nsf.gov/statistics/nsb0602/*

[71] This is in agreement with The National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, DC: National Academies Press, 2005). *http://www.nap.edu/execsumm_pdf/11463.pdf.*

[72] Legislation incorporating similar ideas passed both the House and Senate on August 2, 2007 in the form of H.R. 2272, the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education and Science Act (COMPETES).

[73] The National Board for Professional Teaching Standards (NBPTS) program offers certificates in 24 subject and developmental teaching areas. National Board for Professional Teaching Standards, *http://www.nbpts.org/* (accessed April 19, 2007).

[74] Also recommended in the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995*, (Arlington, VA: National Science Foundation, 1983); National Science Board, *Preparing Our Children: Math and Science Education in the National Interest*, (Arlington, VA: National Science Foundation, 1999). *http://www.nsf.gov/pubs/1999/nsb9931/nsb9931.pdf*; Building Engineering Science Talent, *A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics*, (San Diego, CA: Building Engineering and Science Talent, 2004). *http://www.bestworkforce.org/PDFdocs/BEST_BridgeforAll_HighEdFINAL.pdf*; and Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education*, (Washington, DC: Business-Higher Education Forum, January 2005). *http://www.bhef.com/solutions/MathEduPamphlet_press.pdf*

[75] Critical teaching skills include behavior management and the ability to teach learners from diverse cultural backgrounds and with varying abilities.

[76] An articulation agreement is a policy that allows a student to apply credits earned in specific programs at one institution toward advanced standing, equal transfer, or direct entry into specific programs at another institution.

Selected Acronyms and Abbreviations

ACC	Academic Competitiveness Council
AYP	Adequate Yearly Progress
EHR	NSF Education and Human Resources Directorate
K-12	Kindergarten – 12th grade
MSP	Math and Science Partnership Program
NAEP	National Assessment of Educational Progress
NCLB	No Child Left Behind legislation
NSF	National Science Foundation
NSTC	National Science and Technology Council
OSTP	Office of Science and Technology Policy
P-12	Pre-kindergarten – 12th grade
P-16	Pre-kindergarten – undergraduate education
P-20	Pre-kindergarten – graduate education
Pre-K	Pre-kindergarten
R&RA	NSF Research and Related Activities Directorates
STEM	Science, Technology, Engineering, and Mathematics

Bibliography and Other Related Sources

Abrahams, Camille, Bridget Curran and Theresa Clarke. *Solving Teacher Shortages Through License Reciprocity*. (Denver, CO: National Governors Association Center for Best Practices. February, 2001). *http://www.sheeo.org/quality/mobility/reciprocity.PDF*

ACT, Inc. *Developing the STEM Education Pipeline*. (Washington DC: ACT, 2006). *http://www.act.org/path/policy/pdf/ACT_STEM_PolicyRpt.pdf*

American Association of Colleges of Teacher Education. *Preparing STEM Teachers: The Key to Global Competitiveness.* (AACTE's Day on the Hill, June 20-21, 2007). *http://www.aacte.org/Governmental_Relations/AACTE_STEM_Directory2007.pdf*

American Association for the Advancement of Science. *Atlas of Science Literacy, Volume 1.* (Washington, DC: American Association for the Advancement of Science, 2001).

American Association for the Advancement of Science. *Benchmarks for Science Literacy* (New York: Oxford University Press, 1993). *http://www.project2061.org/publications/bsl/*

American Electronics Association. *Losing the Competitive Advantage? The Challenge for Science and Technology in the United States.* (Washington DC: American Electronics Association, 2005). *http://www.aeanet.org/Publications/idjj_AeA_Competitiveness.asp*

American Electronics Association. *We are Still Losing the Competitive Advantage. Now is the Time to Act.* (Washington DC: American Electronics Association, March, 2007). *http://www.aeanet.org/publications/AeA_Competitiveness_2007.asp*

The Asia Society. *Math and Science Education in a Global Age: What the U.S. Can Learn from China.* (New York: the Asia Society, May 2006). *http://www.internationaled.org/mathsciencereport.pdf*

Barnett, Lynn, Faith San Felice and Madeline Patton. *Teaching by Choice: Community College Science and Mathematics Preparation of K-12 Teachers*. (Washington, DC: American Association of Community College Press, 2005). *http://www.nctaf.org/documents/Teaching_by_Choice_publication_000.pdf*

Building Engineering Science Talent. *A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics.* (San Diego: BEST, 2004). *http://www.bestworkforce.org/PDFdocs/BEST_BridgeforAll_HighEdFINAL.pdf*

Business-Higher Education Forum. *An American Imperative: Transforming the Recruitment, Retention and Renewal of Our Nation's Mathematics and Science Teaching Workforce*. (Washington, DC: Business-Higher Education Forum, 2007). *http://www.bhef.com/news/AnAmericanImperative.pdf*

Business-Higher Education Forum. *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education.* (Hagerstown: Business-Higher Education Forum, January 2005). *http://www.bhef.com/publications/MathEduReport-press.pdf*

Biological Sciences Curriculum Study (BSCS). *A Decade of Action, Sustaining Global Competitiveness: A Synthesis of Recommendations from Business, Industry, and Government for a 21st -century Workforce*. (Colorado Springs, CO: BSCS, 2007). *http://www.bscs.org/pdf/doafullreport.pdf*

Bush, Vannevar. *Science – The Endless Frontier. A Report to the President on a Program for Postwar Scientific Research.* (Washington, DC: U.S. Government Printing Office, 1945). *http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm*

Carcieri, Donald L. *The Governor's Blue Ribbon Panel on Mathematics & Science Education: An Action Plan for Rhode Island.* (Providence, RI: Office of the Governor, October 2005). *http://www.governor.ri.gov/documents/TEC_M&S_FA_LR.pdf*

Carnegie Commission on Science, Technology and Government. *In the National Interest: The Federal Government in the Reform of K-12 Math and Science Education.* (*New* York: Carnegie Corporation, 1991). *http://www.carnegie.org/sub/pubs/science_tech/educ.txt*

The Center for Teaching Quality. *Performance Pay for Teachers: Designing a System that Students Deserve*. (Hillsborough, NC: Center for Teaching Quality, 2007). *http://www.teacherleaders.org/teachersolutions/TSreport.pdf*

The Commission on No Child Left Behind. *Beyond NCLB: Fulfilling the Promise to Our Nation's Children*. (Washington, DC: Aspen Institute, 2007). *http://www.aspeninstitute.org/atf/cf/%7BDEB6F227-659B-4EC8-8F84-8DF23CA704F5%7D/NCLB_Book.pdf*

Committee for Economic Development. *Learning for the Future: Changing the Culture of Math and Science Education to Ensure a Competitive Workforce.* (Washington DC: CED, 2003). *http://www.ced.org/docs/report/report_scientists.pdf*

Committee on Science Learning, Kindergarten Through the Eighth Grade, Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. *Taking Science to School: Learning and Teaching Science in Grades K-8.* (Washington, DC: The National Academies Press, 2007). *http://www.nap.edu/catalog.php?record_id=11625*

Coppola, Ralph K., Joyce Malyn-Smith. *Preparing for the Perfect Storm: A Report on the Forum Taking Action Together Developing a National Action Plan to Address the "T&E" of STEM.* (Reston, VA: International Technology Education Association, November 2006). *http://www.iteaconnect.org/Publications/Promos/NAE.pdf*

The Council of Chief State School Officers Mathematics and Science Education Task Force. *Mathematics and Science Education Task Force Report and Recommendations*. (Washington DC: Council of Chief State School Officers, 2006). *http://www.ccsso.org/content/pdfs/Math%20Science%20Recom%20FINAL%20lowrez.pdf*

Domestic Policy Council of the Office of Science and Technology Policy. *America's Competitiveness Initiative; Leading the World in Innovation.* (Washington DC: Government Printing Office, 2006). *http://www.ostp.gov/html/ACIBooklet.pdf*

The Education for Innovation Initiative. *Tapping America's Potential: The Education for Innovation Initiative Building Public Support*. (Washington DC: The Education for Innovation Initiative, 2005). *http://www.tap2015.org/about/TAP_report2.pdf*

Exxon Education Foundation. *Science Education in the United States: Essential Steps for Achieving Fundamental Improvement. A Report on a Meeting of Educational Leaders Hosted by the Exxon Education Foundation.* (New York, NY: Exxon Education Foundation, January 17-20, 1984).

Finn, Chester, Liam Julian and Michael J. Pertrilli. *To Dream the Impossible Dream: Four Approaches to National Standards and Tests for America's Schools*. (Washington, DC: Thomas B. Fordham Foundation, August 2006). *http://www.edexcellence.net/doc/National%20Standards%20Final%20PDF.pdf*

Friedman, Thomas. *The World Is Flat: A Brief History of the Twenty-first Century.* (New York, NY: Farrar, Straus and Giroux, 2005).

Hirsch, Eric. *Teacher Recruitment, Staffing Classrooms with Quality Teachers.* (Denver, CO: National Conference of State Legislators, February 2001). *http://www.sheeo.org/quality/mobility/recruitment.PDF*

Hussar, W. *Predicting the Need for Newly Hired Teachers in the United States to 2008-09*. (Washington, DC: National Center for Education Statistics, Oct. 15, 1999). *http://nces.ed.gov/pubs99/1999026.pdf*

Hussar, W. *Projections of Education Statistics to 2015, 34th Edition*. (Washington, DC: National Center for Education Statistics Institute of Education Sciences, 2006). *http://nces.ed.gov/pubs2006/2006084.pdf*

Illinois Business Roundtable & Northern Illinois University. *Keeping Illinois Competitive*. (DeKalb, IL: Northern Illinois University, June 2006). *http://www.keepingillinoiscompetitive.niu.edu/ilstem/pdfs/STEM_ed_report.pdf*

Ingersoll, R. *Is There Really a Teacher Shortage?* (Center for the Study of Teaching and Policy, 2003). *http://depts.washington.edu/ctpmail/PDFs/Shortage-RI-09-2003.pdf*

Ingersoll, R. *Turnover Among Math and Science Teachers in the U.S.* (Washington, DC: Department of Education/National Commission on Mathematics and Science Teaching for the 21st Century, 2000). *http://www.ed.gov/inits/Math/glenn/Ingersollp.doc*

International Technology Education Association. *Standards for Technological Literacy: Content for the Study of Technology.* (Reston, VA: International Technology Education Agency, 2000). *http://www.iteaconnect.org/TAA/PDFs/xstnd.pdf*

Levine, Arthur. *Educating School Teachers*. (Washington, DC: The Education Schools Project, September 2006). *http://www.edschools.org/pdf/Educating_Teachers_Report.pdf*

Malcolm, Shirley, Joan Abdallah, et al. *A System of Solutions: Every School, Every Student.* (Washington DC: American Association for the Advancement of Science, 2005). *http://www.aaas.org/programs/centers/capacity/documents/GELongReport.pdf*

National Academy of Sciences, National Academy of Engineering and Institute of Medicine of the National Academies. *Rising Above the Gathering Storm: Energizing and Employing America to a Brighter Economic Future.* (Washington DC: National Academies Press, October 2005). *http://www.nap.edu/execsumm_pdf/11463.pdf*

National Association of System Heads (NASH). *Turning the Tide: Strategies for Producing the Mathematics and Science Teachers Our Schools Need.* (Washington, DC: NASH, November 2006). *http://www2.edtrust.org/NR/rdonlyres/7DCD6A7C-980C-4EA7-BE99-80D0EA3734AF/0/TurningTheTide.pdf*

National Center on Education and the Economy. *Tough Choices, Tough Times: The Report of the New Commission on the Skills of the American Workforce*. (Washington, DC: National Center on Education and the Economy, 2007). *http://skillscommission.org*

National Council of Teachers of Mathematics. *Curriculum Focal Points: From Pre-Kindergarten through Grade 8 Mathematics*. (Reston, VA: National Council of Teachers of Mathematics, 2006). *http://www.nctmmedia.org/cfp/front_matter.pdf*

National Council of Teachers of Mathematics. *Principles and Standards for School Mathematics.* (Reston, VA: National Council of Teachers of Mathematics, 2000).

National Education Summit on High Schools. *An Action Agenda for Improving America's High Schools.* (Washington DC: Achieve, Inc and the National Governor's Association, 2005). *http://www.nga.org/Files/pdf/0502ACTIONAGENDA.pdf*

National Governors Association. *Innovation America Brochure*. (Washington, DC: National Governors Association, 2006). *http://www.nga.org/Files/pdf/06NAPOLITANOBROCHURE.pdf*

National Governors Association. *Innovation America: Building a Science, Technology, Engineering and Math Agenda.* (Washington, DC: National Governors Association, 2006). *http://www.nga.org/Files/pdf/0702INNOVATIONSTEM.PDF*

National Governors Association and The Council on Competitiveness. *Innovation America: A Partnership.* (Washington, DC: National Governors Association, February 24, 2007) *http://www.nga.org/Files/pdf/0702INNOVATIONPARTNERSHIP.PDF*

National Innovation Initiative. *Innovate America.* (Washington DC: Council on Competitiveness, March 2004). *http://www.compete.org/*

The National Research Council. *National Science Education Standards.* (Washington, DC: National Academies Press, 1996). *http://www.nap.edu/openbook.php?isbn=0309053269*

The National Science Board. *America's Pressing Challenge - Building a Stronger Foundation; A Companion to Science and Engineering Indicators.* (Arlington, VA: National Science Foundation, 2006). *http://www.nsf.gov/statistics/nsb0602/nsb0602.pdf*

The National Science Board. *Communicating Science and Technology in the Public Interest*. (Arlington, VA: National Science Foundation, August 3, 2000). *http://www.nsf.gov/nsb/documents/2000/nsb0099/nsb0099.htm*

The National Science Board. *An Emerging and Critical Problem of the Science and Engineering Labor Force: A Companion to the Science and Engineering Indicators.* (Arlington, VA: National Science Foundation, March 2004). *http://www.nsf.gov/statistics/nsb0407/nsb0407.pdf*

The National Science Board. *Preparing Our Children: Math and Science Education in the National Interest.* (Arlington, VA: National Science Foundation, March 1999). *http://www.nsf.gov/pubs/1999/nsb9931/nsb9931.pdf*

The National Science Board. *Undergraduate Science, Mathematics and Engineering Education.* (Arlington, VA: Government Printing Office, March 1986).

National Science Board Commission on Pre-college Education in Mathematics, Science and Technology. *Educating Americans for the 21st Century: A Plan of action for improving mathematics, science and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995.* (Washington DC: National Science Foundation, March 1983).

National Science and Technology Council Committee on Science Subcommittee on Education and Workforce. *Review and Appraisal of the Federal Investment in STEM Education Research.* (Washington, DC: Office of the President, October, 2006). *http://www.ostp.gov/nstc/html/ReviewAppraisaloftheFederalInvestmentSTEMEducationResearchOctober06.pdf*

President's Council of Advisors on Science and Technology. *Sustaining the Nation's Innovation Ecosystem: Maintaining the Strength of Our Science and Engineering Capabilities.* (Washington DC: Government Printing Office, March 2004). *http://www.ostp.gov/PCAST/FINALPCASTSECAPABILITIESPACKAGE.pdf*

Princiotta, D. and Bielick, S. *Homeschooling in the United States: 2003.* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 2005). *http://nces.ed.gov/pubs2006/2006042.pdf*

Project Kaleidoscope. *Report on Reports II. Transforming America's Scientific and Technological Infrastructure: Recommendations for Urgent Action*. (Washington, DC: Project Kaleidoscope, 2006). *http://www.pkal.org/documents/ReportOnReportsII.cfm*

Ruppert, Sandra S. *Improving Pension Portability for K-12 Teachers.* (Denver, CO: Educational Systems Research, February, 2001). *http://www.sheeo.org/quality/mobility/pension.PDF*

Skandera, Hanna and Richard Sousa. *Mobility and the Achievement Gap*. (Stanford, CA: Board of Trustees of Leland Stanford Junior University, 2007). *http://www.hoover.org/publications/digest/4488356.html*

The Task Force on the Future of American Innovation. *The Knowledge Economy: Is the United States Losing its Competitive Edge?* (Washington DC: Task Force on the Future of America's Innovation, 2005). *http://futureofinnovation.org/PDF/Benchmarks.pdf*

The Teaching Commission. *Teaching at Risk: A Call to Action.* (Washington DC: The Teaching Commission, 2004). *http://www.ecs.org/html/offsite.asp?document=http%3A%2F%2Fftp%2Eets%2Eorg%2Fpub%2Fcorp%2Fttcreport%2Epdf*

The Technology CEO Council. *Choose to Compete: How Innovation, Investment, and Productivity Can Grow U.S. Jobs and Ensure American Competitiveness in the 21st Century.* (Washington, DC: Technology CEO Council, 2004). *http://www.cspp.org/documents/choosetocompete.pdf*

U.S. Chamber of Congress. *Leaders and Laggards: A State-by-State Report Card on Educational Effectiveness.* (Washington, DC: U.S. Chamber of Commerce, 2007). *http://www.uschamber.com/icw/reportcard/default#top*

The U.S. Commission for National Security/21st Century. *Road Map for National Security: Imperative for Change" (Phase III).* (Washington DC: Government Printing Office, February 2001). *http://cryptome.sabotage.org/nssg3-01.htm*

U.S. Department of Education. *Report of the Academic Competitiveness Council.* (Washington, DC: U.S. Department of Education, 2007). *http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf*

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics. *Mapping 2005 State Proficiency Standards Onto the NAEP Scales Research and Development Report*. (Washington, DC: Department of Education, June 2007). *http://nces.ed.gov/nationsreportcard/pdf/studies/2007482.pdf*

U.S. Department of Education National Commission on Excellence in Education. *A Nation at Risk: The Imperative for Educational Reform.* (Washington, DC: Government Printing Office, 1983). *http://www.ed.gov/pubs/NatAtRisk/index.html*

U.S. Department of Education National Commission on Mathematics and Science Teaching. *Before It's Too Late: A Report to the Nation.* (Washington, DC: Government Printing Office, March 2000). *http://www.ed.gov/inits/Math/glenn/report.pdf*

Appendix A

Proposed National Council for STEM Education Membership

The following list is meant to provide examples of the types of representatives who might sit on the National Council for STEM Education and is not meant to be either inclusive or exclusive. Those groups designated here as "permanent seats" with an asterisk are of such importance that the Board recommends that they always have a representative on the Council.

Non-Voting Seats:

*Federal Government (2 permanent seats)
- All Federal agencies, including the national laboratories, are represented by the NSTC STEM Education Committee Co-Chairs

*Congress (8 permanent seats)
- Senate Committee on Health, Education, Labor, and Pensions
- Senate Committee on Commerce, Science and Transportation
- House Committee on Education and Labor
- House Committee on Science and Technology

Voting Seats:

State and Local Governments (6 seats total)
- *State Governors (2 permanent seats)
- *Chief state school officer (2 permanent seats)
- *Local school board representative (1 permanent seat)
- National Association of State Boards of Education (NASBE)
- National School Boards Association (NSBA)
- Education Commission of the States (ECS)
- Council of Great City Schools
- National League of Cities
- National Conference of State Legislatures (NCSL)
- National Alliance of State Science and Mathematics Coalitions (NASSMC)

*National Science Board (1 permanent seat)

STEM Educators (5 seats total)
- *Active classroom teacher (1 permanent seat)
- *School administrator (1 permanent seat)
- National Science Teachers Association (NSTA)
- National Council of Teachers of Mathematics (NCTM)
- International Technology Education Association (ITEA)
- American Association of Physics Teachers (AAPT)
- National Association of Biology Teachers (NABT)
- National Earth Science Teachers Association (NESTA)
- Council of State Science Supervisors (CSSS)
- Association of State Supervisors of Mathematics (ASSM)
- Association for Science Teacher Education (ASTE)
- Computer Science Teachers Association (CSTA)
- STEM education researchers
- Association for Career and Technical Education (ACTE)

<u>Higher Education Associations</u> (3 seats total, 2 permanent seats total)
- *American Association of Community Colleges (AACC) (1 permanent seat)
- Association of American Universities (AAU)
- American Association of Colleges of Teacher Education (AACTE)
- National Association of State Universities and Land Grant Colleges (NASULGC)
- American Association of State Colleges and Universities (AASCU)
- National Association for Research in Science Teaching (NARST)
- American Council on Education (ACE)
- National Council for Accreditation of Teacher Education (NCATE)

<u>Business and Industry Associations</u> (2 seats total)
- Business Roundtable
- Council on Competitiveness
- Business Higher Education Forum (BHEF)
- U.S. Chamber of Commerce
- National Association of Manufacturers (NAM)

<u>Private and Corporate Foundations</u> (2 seats total)
- Bill and Melinda Gates Foundation
- The GE Foundation
- National Math and Science Initiative (NMSI)
- The Sloan Foundation
- The Ford Foundation
- Society of Manufacturing Engineers Education Foundation

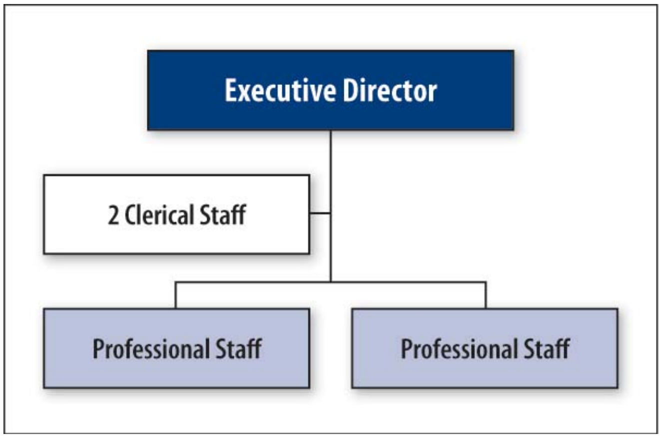
<u>Informal STEM Education</u> (2 seats total)
- Public broadcast media such as Corporation for Public Broadcasting (CPB), Public Broadcasting System (PBS), National Public Radio (NPR)
- Commercial broadcast media such as Discovery Channel, CBS, Fox
- Association of Science-Technology Centers (ASTC)
- Museums
- Internet-based informal STEM resources

<u>STEM Disciplinary Societies</u> (2 seats total)
- The National Academies
- American Association for the Advancement of Science (AAAS)
- Sigma Xi
- American Chemical Society (ACS)
- American Meteorological Society (AMS)
- American Geological Institute (AGI)
- American Mathematical Society (AMS)
- Mathematical Association of America (MAA)
- American Physical Society (APS)
- Federation of American Societies for Experimental Biology (FASEB)
- Institute of Electrical and Electronics Engineers (IEEE)
- American Society of Mechanical Engineers (ASME)
- American Institute of Aeronautics and Astronautics (AIAA)
- American Geophysical Union (AGU)
- Materials Research Society (MRS)
- American Institute of Biological Sciences (AIBS)
- Association for Computing Machinery (ACM)
- Computing Research Association (CRA)

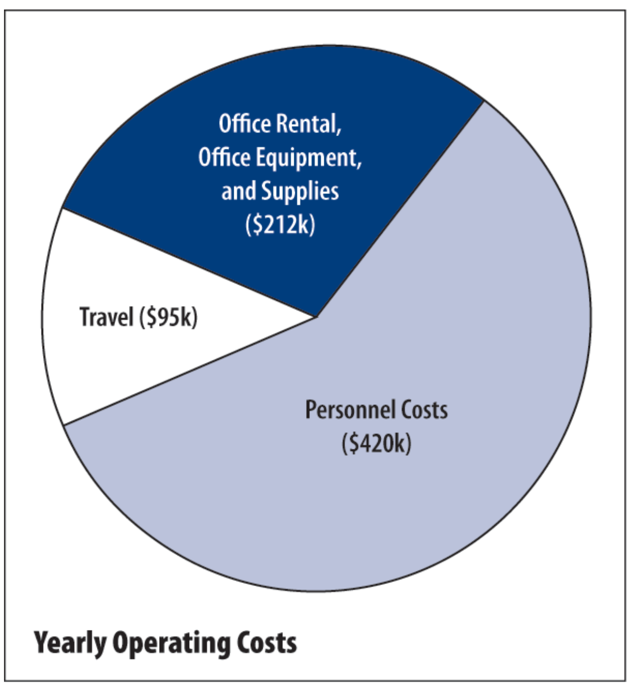
Appendix B

Proposed National Council for STEM Education Operational Staff and Budget

The scope of the Council as envisioned suggests the need for a small cadre of professional staff. The day-to-day operations of the Council could be staffed with one executive director, two professional staff, and two clerical staff.



Initial cost estimates suggest a needed yearly budget of $700,000-800,000 for operational costs to pay for personnel, office space, equipment, and travel.



Appendix C

National Science Board Hearings on 21st Century Education in Science, Mathematics, and Technology

HEARING PARTICIPANTS

Hearing 1
December 7, 2005

Washington, DC
Cannon House Office Building

Participant	**Affiliation***
	National Science Board
Dr. Warren Washington	NSB Chairman Senior Scientist and Section Head National Center for Atmospheric Research
Dr. Dan E. Arvizu	NSB Member Director, National Renewable Energy Laboratory
Dr. Steven C. Beering	NSB Member President Emeritus, Purdue University
Dr. Ray M. Bowen	NSB Member President Emeritus, Texas A&M University
Dr. Elizabeth Hoffman	NSB Member President Emerita, University of Colorado
Dr. Douglas D. Randall	NSB Member Professor of Biochemistry and Director, Interdisciplinary Program on Plant Biochemistry and Physiology, University of Missouri
Dr. Michael Crosby	NSB Executive Officer and Director, National Science Board Office
	Members of Congress
Congressman Sherwood Boehlert	Chairman, Committee on Science
Congressman John Abney Culberson	Subcommittee on Science, State, Justice, and Commerce, Committee on Appropriations

* Affiliation listed as at time of hearing.

Congressman Vernon J. Ehlers	Chairman, Subcommittee on Environment, Technology, and Standards, Committee on Science
Congressman Bart Gordon	Ranking Member, Committee on Science
Congresswoman Eddie Bernice Johnson	Committee on Science
Congressman Frank Wolf	Chairman, Subcommittee on Science, State, Justice, and Commerce, Committee on Appropriations
	Department of Education and the National Science Foundation
Mr. Thomas Luce	Department of Education, Assistant Secretary, Office of Planning, Evaluation and Policy Development
Dr. Arden L. Bement, Jr.	Director, National Science Foundation
Dr. Donald Thompson	National Science Foundation, Directorate for Education and Human Resources, Acting Assistant Director
	Other Participants
Ms. Mary Vermeer Andringa	President and COO, Vermeer Manufacturing Company
Mr. William Archey	President and CEO, American Electronics Association
Mr. Alfred Berkeley	Chairman, Pipeline Trading Systems, LLC
Mr. Ronald Bullock	CEO, Bison Gear and Engineering
Dr. Raymond Cline	Vice President of Innovation Integration, EDS
Dr. Jack Collette	Senior Consultant, Delaware Foundation for Science and Mathematics
Dr. Cecily Cannan Selby	Affiliated Scholar, Steinhardt School of Education, New York University
Dr. David Shaw	Chairman, D. E. Shaw & Co., Inc.
Dr. Robert Tinker	President, The Concord Consortium
Dr. Gerald Wheeler	Executive Director, National Science Teachers Association (NSTA)

Hearing 2
February 10, 2006

Boulder, Colorado
University of Colorado

Participant	**Affiliation**
	National Science Board
Dr. Warren M. Washington	NSB Chairman Senior Scientist and Section Head National Center for Atmospheric Research
Dr. Dan E. Arvizu	NSB Member Director, National Renewable Energy Laboratory
Dr. Steven C. Beering	NSB Member President Emeritus, Purdue University
Dr. Ray M. Bowen	NSB Member President Emeritus, Texas A&M University
Dr. Kelvin K. Droegemeier	NSB Member Regents' Professor & Roger and Sherry Teigen Presidential Professor; Weathernews Chair of Applied Meteorology; Director, Center for Analysis and Prediction of Storms; and Director, Sasaki Institute, University of Oklahoma
Dr. Kenneth M. Ford	NSB Member Director, Institute for Human and Machine Cognition, University of West Florida
Dr. Daniel E. Hastings	NSB Member Director, Engineering Systems Division and Professor, Aeronautics and Astronautics and Engineering Systems, Massachusetts Institute of Technology
Dr. Elizabeth Hoffman	NSB Member President Emerita, University of Colorado
Dr. Alan I. Leshner	NSB Member Chief Executive Officer, American Association for the Advancement of Science
Dr. Douglas D. Randall	NSB Member Professor of Biochemistry and Director, Interdisciplinary Program on Plant Biochemistry and Physiology, University of Missouri
Dr. Michael G. Rossman	NSB Member Hanley Distinguished Professor of Biological Sciences, Purdue University

Dr. Daniel Simberloff	NSB Member Nancy Gore Hunger Professor of Environmental Science, University of Tennessee
Dr. Jon C. Strauss	NSB Member President, Harvey Mudd College
Dr. Kathryn D. Sullivan	NSB Member Science Advisor, Center of Science and Industry (COSI)
Dr. Jo Anne Vasquez	NSB Member Mesa Public Schools (Retired) Gilbert, Arizona
Dr. Arden L. Bement, Jr.	NSB Member Ex Officio Director, National Science Foundation
Dr. Michael P. Crosby	NSB Executive Officer and Director, National Science Board Office
	Members of Congress
Congressman Mark Udall	Ranking Member, Subcommittee on Space and Aeronautics, Committee on Science
	Colorado Spokespersons
President Hank Brown	President, University of Colorado System
Mr. Randy DeHoff	Board Member, Colorado Department of Education, Colorado State Board of Education
Senator John Evans	Senator, Colorado General Assembly Senate Education Committee
Representative Keith King	Representative, Colorado General Assembly House Education Committee
Senator Susan Windels	Senator, Colorado General Assembly, and Chair, Senate Education Committee
	Panelists
Dr. Michael Barnett	Senior Physicist and Educator, Lawrence Berkeley National Laboratory
Dr. Ruth David	President and CEO, Analytic Services, Inc.
Dr. Joseph Heppert	Chairman, Department of Chemistry, University of Kansas
Dr. Leon Lederman	Fermilab Director Emeritus and Chairman, Teachers Academy for Mathematics and Science

Dr. Shirley Malcom	Head, Directorate for Education, American Association for the Advancement of Science (AAAS)
Mr. Timothy McCollum	7-12 Science Teacher, Charleston Middle School, Charleston, Illinois
Mr. Michael Miravalle	President and CEO, Dolphin Technology, Inc.
Dr. Cindy Moss	Director of Science, K-12, Charlotte Mecklenburg Schools, Charlotte, North Carolina
Ms. Judith Sandler	Vice President, Education Development Center, Inc.
Dr. Thomas Smith	Professor, Chemistry and Microsystems Engineering Rochester Institute of Technology
Dr. Cindy Stevenson	Superintendent, Jefferson County Public Schools, Golden, Colorado
Mr. James Von Ehr	Founder, Chairman, and CEO, Zyvex Corp.
Dr. Karin Wiburg	Associate Dean for Research, New Mexico State University
Ms. Della Williams	President and CEO, Williams-Pyro, Inc.
Ms. Robin Willner	Vice President, Global Community Initiatives, IBM Corporation

Hearing 3
March 9, 2006

Los Angeles, California
University of Southern California

Participant	Affiliation
	National Science Board
Dr. Steven C. Beering	NSB Member President Emeritus, Purdue University
Dr. Elizabeth Hoffman	NSB Member President Emerita, University of Colorado
Dr. Jon C. Strauss	NSB Member President, Harvey Mudd College
Dr. Jo Anne Vasquez	NSB Member Mesa Public Schools (Retired) Gilbert, Arizona
Dr. Michael P. Crosby	NSB Executive Officer and Director, National Science Board Office

	University of Southern California Spokespersons
Dr. C.L. Max Nikias	Provost, University of Southern California
President Steven B. Sample	President, University of Southern California
Dr. Karen Symms Gallagher	Dean, School of Education, University of Southern California
	Panelists
Dr. Dennis Bartels	President, TERC Science and Math Learning
Chancellor Denice Denton	Chancellor, University of California, Santa Cruz
Dr. Eugene Garcia	Dean, School of Education, Arizona State University
Dr. James Gentile	President, Research Corporation
Dr. Dean Gilbert	President, California Science Teachers Association
Dr. Terry Joyner	Chief Academic Officer, Cincinnati Public Schools
Ms. Maria Alicia Lopez-Freeman	Executive Director, California Science Project
Dr. Lillian McDermott	Director, Physics Education Group, University of Washington
Dr. Willie Pearson, Jr.	Chair, School of History, Technology, and Society, Georgia Institute of Technology
Mr. Larry Prichard	Superintendent, Carter County, Kentucky
Dr. Jody Priselac	Director, Center X, University of California, Los Angeles
Dr. Rc Saravanabhavan	Dean, School of Education, Howard University
Mr. George Scalise	President, Semiconductor Industry Association
Dr. Robert Semper	Executive Director, Exploratorium
President Priscilla Slade	President, Texas Southern University
Dr. Elizabeth Stage	Director, Lawrence Hall of Science, University of California at Berkeley
Dr. Herbert Thier	Founding Director, Science Education for Public Understanding Program, University of California at Berkeley
Dr. Todd Ullah	K-12 Science Director, Los Angeles Unified School District
Dr. Jerry Valadez	K-12 Science Coordinator, Fresno Unified School District
Mr. Andrew Viterbi	President, Viterbi Group, LLC

Appendix D

Charge to the Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics*

Background

Over the last two decades, numerous reports and statements from eminent bodies representing the broad range of national interests in science and technology literacy in U.S. society and skills in the U.S. workforce have sounded alarms concerning the condition of pre-K-16 education in science and technology areas. Nevertheless, our Nation's education competitiveness continues to slip further behind the rest of the world. A number of spokespersons for the science and engineering education communities have urged the National Science Board (the Board) to undertake an effort similar to the 1982-1983 Board Commission on Pre-college Education in Mathematics, Science, and Technology. Congressional Appropriations Committee report language for FY 2006 stated that they strongly endorse the Board taking steps to "establish a commission to make recommendations for the National Science Foundation (NSF) and Federal Government action to achieve measurable improvements in the Nation's science education at all levels," and expects the Board to "report the commission's findings and recommendations to the Committee at the conclusion of the commission's work." Subsequently, the Board held three public hearings to explore the merit of establishing a special Commission on Education for the 21st Century. By approving this charge, the Board has decided to establish such a Commission to develop a national action plan addressing issues that have inhibited effective reform of U.S. science, technology, engineering, and mathematics (STEM) education.

Statutory Basis Under the NSF Act

Under 42 U.S.C. § 1862 (d): "The Board and Director shall recommend and encourage the pursuit of national policies for the promotion of…education in science and engineering." 42 U.S.C. § 1863(h) authorizes the National Science Board "to establish such special commissions as it may from time to time deem necessary for the purposes of this chapter." The Board Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics (the Commission) will conduct its activities according to the Federal Advisory Committee Act (FACA) and other authorities, including applicable conflict-of-interest laws and regulations.

Objectives

The Commission will make recommendations to the Nation through the Board for a bold new action plan to address the Nation's needs, with recommendations for specific mechanisms to implement an effective, realistic, affordable, and politically acceptable long-term approach to the well-known problems and opportunities of U.S. pre-K-16 STEM education. The objective of a national action plan is to effectively employ Federal resources cooperatively with those of stakeholders from all sectors including but not limited to: Federal, State and local government agencies; parents, teachers and students; colleges – including community colleges; universities, museums and other agents of formal and informal education outside the K-16 systems; industry; and professional, labor and

*NSB-06-39, March 30, 2006

public interest organizations to encourage and sustain reform of the national pre-K-16 STEM education system to achieve world class performance by U.S. students, prepare the U.S. workforce for 21st century skill needs, and ensure national literacy in science and mathematics for all U.S. citizens.

In developing a national action plan, the Commission will address the following issues and identify the specific role of NSF in each:

- Improving the quality of pre-K-16 education related to both general and pre-professional training in mathematics, engineering and the sciences, including, but not limited to: the availability of competent teachers; the adequacy and currency of curricula, materials, and facilities; standards and trends in performance, as well as promotion, graduation and higher-education entrance requirements; and comparison with performance and procedures of other countries.

- Identifying critical aspects in the entry, selection, education and exploitation of the full range of potential talents, with special attention to transition points during the educational career where loss of student interest is greatest; and recommend means to assure the most effective education for all U.S. students as well as future scientists, engineers and other technical personnel.

- Improving mathematics and science programs, curricula, and pedagogy to capitalize on the Nation's investment in educational research and development and appropriate models of exemplary education programs in other countries.

- Promulgating a set of principles, options and education strategies that can be employed by all concerned, nationwide, to improve the quality of secondary school mathematics and science education in the 21st century, as an agenda for promoting American economic strength, national security, employment opportunities, and social progress that will support U.S. pre-eminence in discovery and innovation.

Membership and Structure

The Board Commission will consist of up to fifteen (15) members appointed by the Chairman of the Board, in consultation with the full Board, the Executive Branch, Congress and other stakeholders. The Board Chairman will designate a Commission chairperson and vice chairperson from among the members. No more than three Commission members will be appointed from current Board membership. Commission members will be persons whose wisdom, knowledge, experience, vision or national stature can promote an objective examination of mathematics, science and technology education in the pre-K-16 system and develop a bold new national action plan for the 21st century.

A quorum of the Commission will be a majority of its members. Terms of service of members will end with the termination of the Commission. The Commission may establish such working groups, as it deems appropriate. At least one member of each working group shall be a member of the Commission. A Commission member will chair each working group, which will present to the Commission findings and recommendations for consideration by the Commission. Timely notification of the establishment of a working group and any change therein, including its charge, membership and frequency of meetings will be made in writing to the Executive Secretary or his/her designee. Management (including Executive Secretary and Designated Federal Official (DFO)) and staff services will be provided by the Board Office under the direct supervision of the Board's Executive Officer. Commission working groups will act under policies established by the Commission, in accordance with FACA and other applicable statutes and regulations.

Meetings

The Commission will meet as requested by the chairperson. Working groups will report to the full Commission and will meet as required at the call of their chairperson with the concurrence of the Commission chair. Meetings will be conducted, and records of proceedings will be kept, in accordance with applicable laws and regulations.

Expenses

Per diem and travel expenses will be paid in accordance to Federal Travel Regulations.

Reporting

The future action plan will especially focus on the appropriate role of NSF in collaboration and cooperation with other Federal agencies, State government, local school districts, gatekeepers, business and industry, informal STEM educational organizations, professional associations, scientific organizations, and parents and other citizens interested in improving education in mathematics, science and technology for our Nation's children. In addition to its final report, which is expected 12 months from the initial meeting, the Commission will submit to the Board periodic progress reports at least every 4 months. The Commission will develop an action plan that includes a plan for public dissemination and outreach for Commission activities, recommendations, and reports.

Warren M. Washington
Chairman

Appendix E

Members of the Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics*

Dr. Leon M. Lederman, Commission Co-Chairman, Resident Scholar, Illinois Mathematics and Science Academy

Dr. Shirley M. Malcom, Commission Co-Chairman, Head, Directorate for Education and Human Resources Programs, American Association for the Advancement of Science (AAAS)

Dr. Jo Anne Vasquez, Commission Vice-Chairman, Member, National Science Board; Director of Policy and Outreach, Center for Research on Education in Science, Mathematics, Engineering and Technology, Arizona State University

The Honorable Nancy Kassebaum Baker, Former United States Senator (R-KS)

Dr. George R. Boggs, President and CEO, American Association of Community Colleges (AACC)

Mr. Ronald D. Bullock, Chairman and CEO, Bison Gear and Engineering, St. Charles, IL

Dr. Karen Symms Gallagher, Dean, Rossier School of Education, University of Southern California

Dr. James M. Gentile, President, Research Corporation, Tucson, AZ

Dr. Dudley R. Herschbach, Frank B. Baird, Jr., Research Professor of Science, Harvard University

Ms. María Alicia López-Freeman, Executive Director, California Science Project

Dr. Maritza B. Macdonald, Director of Professional Development, American Museum of Natural History, New York City

Mr. Timothy D. McCollum, Science Teacher, Charleston (IL) Middle School

Dr. Cindy Y. Moss, Director of K-12 Science, Charlotte/Mecklenburg (NC) Public Schools

Mr. Larry G. Prichard, Superintendent, Carter County (KY) Schools

The Honorable Louis Stokes, Former United States Congressman (D-OH)

~ ~ ~ ~ ~

Dr. Elizabeth Strickland, Commission Executive Secretary

*NSB/STEMCOMM-06-1, May 10, 2006, revised January 16, 2007

Appendix F

Appendix F is the final draft report of the Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics as submitted to the National Science Board on March 15, 2007. Although much of the Commission's advice was incorporated into the Board's action plan, the Commission's report to the Board does not necessarily represent either the work or views of the National Science Board.

Draft Report of the Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics

Introduction

In 2006, the National Science Board (the Board) established the Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics (STEM) with the strong endorsement of Congressional Appropriations Committee language.[1] The Commission was charged with developing a bold, new action plan to implement the findings of the many previous panels, taskforces, commissions, and workshops that have called for a major transformation of STEM education in the United States (U.S.).

The Board's own report to Congress, *Science and Engineering Indicators 2006*, summarizes much of the data on education performance by U.S. students that compelled the Board to act. Numerous factors have informed this action plan including the high degree of attention directed toward STEM education; the growing concern from business and industry leaders, as well as from the nation's governors, regarding America's economic future; and the findings of the Board's recent education policy statement, *America's Pressing Challenge – Building a Stronger Foundation.*

The Commission has read and incorporated the work of previous groups in the preparation of this action plan and is mindful that many previous recommendations have never been implemented. Therefore, we set about to imagine the mechanisms, processes, structures, and metrics that would lead to implementation. In the report that follows, we present a set of actions that, taken together, would lead to the transformation of STEM education in the United States. These actions necessarily depend on the good faith and the coherent and comprehensive efforts of many actors (i.e., local school systems, government at all levels, universities, community colleges, professional societies, Federal agencies, corporate sponsors, and accrediting bodies).

The Nation has successfully faced challenges to the STEM education system in the past - challenges that led us to re-examine our actions and chart a new path in STEM education and research. It is that history and our responses to it that we recall below.

The shock effect of the Soviet success in launching Sputnik in 1957 jarred the United States into taking a series of appropriate actions to win the space race. For example, in less than a year of Sputnik's launch, the United States Congress established the National Aeronautics and Space Administration (NASA) to oversee the task of developing a successful U.S. space program. The Defense Advanced Research Projects Agency (DARPA) was similarly established because the Department of Defense had no such ability to utilize up-to-the minute technology in support of national security. A science advisory system to the President was also established to provide the executive branch with scientific and technological advice. Furthermore, precedent-shattering Federal assistance to public education was established via the National Defense Education Act[2] (NDEA). Providing critical support and organizational infrastructure to the Nation's STEM development was deemed necessary to confronting the challenges of that day.

However, despite the importance of STEM fields to our Nation's economic development and competitiveness, today, almost 50 years after Sputnik, our Federal system has no entity specifically charged with and enabled to implement STEM education initiatives. These initiatives span across many Federal agencies, the vast K-12 education system, universities (including community colleges), and the informal learning community. As we studied the needs of our complex system, it became clear that a new structure is needed: a national, non-Federal entity to support more cohesive and research-based approaches to locally based reform.

We are mindful of the difficulty in orchestrating, facilitating, and coordinating the disparate efforts of many actors with responsibility for different components of a highly distributed education system. Thus, we are making a single recommendation to Congress:

Congress should charter a national body to implement, in partnership with the National Governors Association, a national system for 21st century science, technology, engineering, and mathematics education.

The National Institute for STEM Educational Transformation

The National Institute for STEM Educational Transformation (NISET), the provisional name given to this body, would be chartered by Congress to work with the National Governors Association (NGA) and other organizations to facilitate, coordinate, and support implementation of the STEM education action plan outlined in this document. NISET would be modeled on the structure of the National Academy of Sciences (NAS).

The NAS was chartered by Congress in 1863 with the following mission: "The Academy shall, whenever called upon by any department of the government, investigate, examine, experiment and report upon any subject of science or art, the actual expense of such investigation to be paid from appropriation but the Academy shall receive no compensation whatever for any services to the Government of the United States." Thus, the Federal Government assured itself access to scientific advice at the highest level by creating an entity independent of the Federal structure. NAS has served this critical function over 140 years since its founding. Today, NAS is comprised of 600 members, many of whom are the most productive leaders in all fields of science in the nation. The original structure of the Academy was so successful that the National Academy of Engineering and the Institute of Medicine were later established to complement the work of the "parent" entity, and subsequently formed what we know today as the National Academies. The U.S. Government depends on the input and advice of the Academies for important tasks related to science, even though a number of Federal science agencies exist.

We propose that the newly chartered NISET operate under the same model as the National Academies. NISET should collaborate with other government agencies that handle STEM education activities and the NGA to focus and maintain national attention on STEM education in the nation. NISET would be composed of a number of outstanding persons capable of exercising national leadership in those domains relevant to STEM education: business, education, science, engineering, higher education, and public policy. Representation would be included from such agencies as the National Academies, NSF, the Department of Education (ED), state pre-K through graduate (P-20) education councils, the Council of Chief State School Officers (CCSSO), the Education Commission of the States, the National School Boards Association (NSBA), and others. This new entity would constitute a powerful consortium whose objectives would be to encourage and ensure the implementation and monitoring of STEM education initiatives in such a way as to generate a nationwide transformation.

The absence of management and oversight functions and the diversity of structure and membership should discourage the notion that the NISET is "just another layer of bureaucracy." Rather, the functions are to encourage the conduct and dissemination of the results of research and evaluation and to incubate innovative proposals that emerge from Commissions like this one. There will be future crises in our nation, which will call for new education initiatives. Since NISET would be a permanent addition to the array of national education entities, its implementation, coordination, and monitoring role - exercised in collaboration with the state education councils - would be available to all future Commissions.

NISET would also be expected to straddle and cross boundaries. To have legitimacy and appeal, it must be widely representative. Its value resides in its ability to facilitate, coordinate, support and monitor knowledge generating and knowledge sharing functions. It is designed as a beacon and an enabler rather than an enforcer. Agencies and departments would participate because their missions would be supported and their support leveraged. NISET could provide the "glue" that would bring state and local groups to the table.

Our vision of the value of this proposal is exciting. Like the National Academies, NISET is an intellectual structure now absent from our system but with far reaching possibilities and long lasting impact.

P-20 Councils

To complement the work of NISET, the Commission endorses the recommendation made in previous reports to encourage all states to form effective P-20 education councils. Approximately half of all U.S. states have already established P-20 councils. New education initiatives would be planned and marketed within these councils, and implementation would be supported. This is a logical place to begin discussing and enabling state-level, system-wide transformation of education in ways that support STEM education change. Supported by NISET, these state councils would facilitate the creation of local councils. The state councils would report to their respective governors and act as apolitical bodies in order to overcome partisan challenges. Council members would be highly respected for what they bring individually and collectively to deliberations: integrity, judgment, wisdom, political savvy, knowledge, and the vision to bring the United States from the present to the possible. Just as the presence of community members, business leaders, and local philanthropy representatives would be needed for external legitimacy, so too are representatives from various stakeholder groups needed, such as elected officials, boards of education, principals, superintendents, unions, parent groups, community college/university leaders, for achieving internal legitimacy.

P-20 councils would gain important information to benchmark their activities, share research and evaluation of promising practices, and be supported by NISET, the facilitating national entity responsible for disseminating information and providing assistance to inform local decision making. The councils would consider how the thoughtful and judicious use of technology in education might create new learning opportunities, help to build and extend capacity, link educational "haves and have-nots," expand the time for learning, and close the resource gaps that are found across systems. The larger STEM community would also need to be engaged at every level of dialogue and participation, including as members of councils, to guide the changes that they will need to make within their own community, to develop needed innovations in teaching and learning, as well as to assist others in their efforts. For example, the councils would need to consider STEM teacher recruitment and retention and how salary levels can be raised to respond to market forces for such highly skilled professionals. The councils would need also to focus on how well the system is serving *all* students, including those with disabilities, English language learners, girls and boys of all racial/ethnic groups, rural and urban schools and so on, as called for under No Child Left Behind (NCLB) legislation. They would also need to consider and advise on the relative value of investing early, such as in pre-school programs, where research suggests a high payoff for enhancing school readiness, especially for students most likely otherwise to be left behind. They may consider other issues related to "time for learning," such as extension or modification of the school day, week or year. Whatever innovation is put in place should be well evaluated for effectiveness. Whatever is adapted from others should be formatted for local success and be widely shared. This will ensure that the councils, in coordination with NISET, collectively become a powerful community for learning as well as an engine for transformation of STEM education in the United States.

The Campaign for America's Future

Another task for NISET, and an essential element in the implementation of bold transformation, is the development of a popular consensus that an educational system, designed in the 19th and 20th centuries, can no longer serve the Nation without major changes. Thus, NISET can be called upon to appeal to the opinion leaders of the nation, the business community, scientists, engineers, educators, teachers, lawyers, clergy, media, leaders of higher education, politicians, and ordinary citizens to help explain the stakes. Additionally, NISET can be used to enlist support for changes such as those being advanced by our Commission and others and through state and local councils. We must sell the idea that our children deserve to look ahead to a future of hope and prosperity. We must help citizens understand the anachronistic nature of most schooling today, in which "post-Internet" young people are dropped into technology-poor environments, where they do not have the type of instruction, level of rigor, or expectations needed to address the challenges they will inherit or to imagine and create the future. We need to help the American public understand that the innovation system that has oftentimes given us products of American ingenuity and creativity is at risk. Seeking wide public support will require engagement with professionals who have public outreach expertise, and will also require the collaboration of media leaders.

Conclusions

The ingredients of this action plan rest heavily upon the new national NISET, which we present as a mechanism to enable a continuous transformation of STEM education and ultimately, of all U.S. education. However, we must be aware that the success of NISET requires P-20 councils, the collaboration of the NGA, the recognition and enthusiasm of the U.S. Congress, and a strong base of public support.

Our single major recommendation, to create an entity to support and assist in the effort, is largely made with careful consideration of our past failures to implement reform. Each member of an orchestra has a responsibility to perform at his or her highest level to create the symphony. Orchestrating transformation does not mean that each will play the same notes – it does mean that we will agree to the same music. Let us work together to sustain a strong and vibrant country with a robust and adapting economy for the 21st century in a world transformed by science and technology.

A Tale of Two Futures

If we were able to look into the future, we would be able to see the work of this Commission in the light of history. This is not possible. However, by building on current circumstances and conditions, we can imagine possible futures and the outcomes of our actions (or inactions). With this imagining comes some understanding of the possible effects of the choices that we make today. Two scenarios are presented below.

Scenario 1: Embracing the Challenge

The year 2007 was a turning point in U.S. history. Just as the launching of Sputnik 50 years earlier led to critical investments and the creation of many important agencies and initiatives to address the challenge to American security posed by the then Soviet Union, the decision to charter NISET and empower it to work across the many different levels of government, higher education and civil society (with governors, state, Federal and local education agencies, institutes of higher education, accrediting bodies, business, industry, etc.) led to massive transformation of STEM education. Growing concern about the level of U.S. competitiveness in a knowledge-based economy prompted this work.

Programs of in-service STEM education revitalized the STEM teaching corps that was in place at the time. Innovative education and induction initiatives attracted STEM students to teaching and retained qualified educators. Teacher education students participated in exciting, re-vamped, college-level STEM courses and left their programs with enthusiasm for these fields. These highly qualified teachers were deployed into schools across the country where enhanced facilities, a world class curriculum, and exciting technology combined to enhance the science experiences for young people and support a positive attitude and "science way of thinking" for all students. Students emerged from these schools and from informal learning opportunities with 21st century skills, a love of learning, and excitement about STEM as it helped them understand the world around them. Some became STEM professionals; some became innovators, business and political leaders. All were personally enriched and empowered to move with confidence into the future as their lives were increasingly transformed by science and technology. They were more agile workers, better parents, and more informed and engaged citizens. The economy thrived, and the standard of living improved for all, even as the United States reached out to support the use of science and technology (S&T) to address global challenges.

Prior to 2007, there had been good schools, excellent teachers, opportunities for student research, and engagement with problem-based learning, but these were not widespread. All too often, a student's "zip code" was a primary determinant of access, with students from high wealth areas receiving challenging educational experiences, while those in poor, urban, and rural schools were provided with uninspired and uninspiring STEM experiences.

The wake-up call led to unprecedented cooperation, convergence of intent and action and to the creation of a 21st century education for all of America's youth.

Scenario 2: Ignoring the Challenge (or Foregoing the Opportunity)

The NSB Commission issued its report in 2007. Despite its findings and its single recommendation to create an "implementing mechanism" (NISET) to support transformation in STEM education, it was difficult to get political and public traction for collaborative action. States continued to set their own standards and their own pace for change. Standards were often lowered to prevent massive takeover of schools by the states as required under NCLB legislation. The "illusion of rigor" lulled students and their parents into thinking that their children had been adequately prepared for living and working in the knowledge-based economy of the 21st century. However, the lack of knowledge and skills was painfully apparent when they entered higher education or the workforce. This inadequate preparation not only affected the students and their families directly, but in the aggregate, it affected overall U.S. competitiveness as the story of inadequate STEM education was found to have been repeated many times over. Despite the fact that past decisions had led to a weakened U.S. position in the global economy, policymakers "passed" on the challenge of assuming leadership, raising standards, and investing in creating a 21st century education for all children. Funding for education was not directed at transformation. Some students had received a wonderful, rich STEM education with well-prepared teachers and exciting STEM experiences. However, they were the exceptions. All too often family socio-economic and education levels were the main predictors of the quality of the STEM education experiences that students received. The talent of the increasingly diverse student population was left untapped. The STEM employment opportunities outside of education could not be ignored, especially for the most talented STEM educators who, in their frustration with the erosion of conditions in the schools, left to pursue more lucrative options in the workforce. Higher education bemoaned the quality of the STEM preparation of students who came to them, but did not perceive the relationship between the quality of their own teacher education initiatives and the students they would later receive.

Overall, there was a sense of pessimism about the directions that the country was headed. Citizens often voted in opposition to their own self-interest when it came to environmental, energy, and health concerns since they often did not understand what was at stake. Low wage jobs were the rule of the day, and children faced a lower standard of living than that of their parents.

The Bottom Line

Our people are our greatest asset, but failure to educate them could be a liability for us all. Our people, our children, our choice…will they be America's "ace in the hole" or our "Achilles' heel?" It is our move.

Action Plan

The United States can no longer afford to provide its young people with STEM education that is fragmented and uncoordinated across the various components of the formal education system. U.S. students must receive the skills and knowledge of science, technology, engineering, and mathematics within an educational structure that is aligned both horizontally and vertically. Additionally, this structure must be standards-based and nationally coordinated to ensure that all participants are adequately prepared to thrive in a technologically complex 21st century.

The grand challenge of this new century is raising the quality of education for all and narrowing the achievement gap in U.S. STEM education. The STEM education system must incorporate proven practices based on solid research on teaching and learning. The system must provide and enlarge capacity to undertake educational research for the ongoing development and study of innovative improvement practices. A balance must exist between acquiring content knowledge and developing analytical skills such as critical thinking, making connections between ideas, and building a capacity for life-long learning. Students need thoughtfully sequenced classes that focus on depth of understanding, not just coverage of topics. Coordination must be both horizontal among states and vertical across grade levels, from pre-K through graduate education. Undertaking this effort assumes an acceptance of high standards for all students and an acceptance of the value in coherent and coordinated standards, curricula, assessments, as well as professional development opportunities.

The Commission recognizes that a coherent P-20 national system requires:

- Horizontal coordination within and among states;
- Vertical alignment from pre-K through graduate education; and
- Fully integrated teachers in the system.

Addressing the issues posed in this action plan would be the responsibility of state P-20 councils, supported by the national coordinating entity, NISET, which would work closely with the National Governors Association, other state and local based education and STEM based groups, professional societies, teachers and higher education organizations among others. At the Federal level, we propose the National Science and Technology Council[3], Committee on Science, Subcommittee on Education and Workforce Development[4] provide the unified Federal voice that interacts with NISET.

Many different agencies and actors, at all levels, will need to work together to identify the contours of issues related to STEM education transformation in all its dimensions and to accept responsibility to work collectively toward meeting these challenges. We believe that the umbrella that NISET provides will allow an appropriate "implementing and learning community" to emerge.

The Commission was also charged with commenting on the role of the National Science Foundation in STEM education transformation. Statements about its unique role are provided below while other aspects of the NSF role are embedded, where appropriate, in the action plan below. It is clear that while NSF would have a role that would be integrated with other Federal actors, it also bears unique leadership responsibility by virtue of its mandate to see to the health of STEM education in the United States, and its strategic responsibility to focus on the integration of research and education. The comments to the Board about this role are made in recognition of this special context.

The Role of NSF

The National Science Foundation (NSF) has a unique responsibility to shape its own STEM education research and development strategy, in collaboration with the STEM education and research community, in ways that complement and support the larger implementation needs of this collaborative effort. This would mean, for example:

- Promoting innovation in education through support of research that responds to critical needs from the world of practice (such as new ideas that might emerge from school systems and P-20 councils) in addition to those that are initiated within the research programs of experts studying key issues related to STEM education;
- Supporting scientists and engineers who wish to pursue research and development on teaching and learning in education in their fields, perhaps in collaboration with education researchers with complementary and supporting interests and skills;
- Exploring research and development on issues related to scaling up promising practices or new organizational arrangements to support STEM education transformation;
- Finding ways to promote and scale up the successful educational research in order that all communities can benefit from the findings; and
- Building capacity for sustained research programs in STEM education, to ensure that innovative research methodologies, tools, and resources are developed to support deeper understanding of STEM educational issues.

Undertaking these additional roles in STEM education R&D will likely, over time, require new and additional investments from Congress.

The NSF portfolio has evolved over the years, and reflects the history of NSF's leadership in STEM education including basic research on learning; development of instructional materials, tools and resources; technology development; informal science education; pre-service teacher preparation; in-service teacher education; and large systemic initiatives aimed at improving mathematics and science education for all students. In particular, NSF has brought to the field the best knowledge and tools available for the professional development of all teachers. These products can be used by the U.S. Department of Education, other Federal agencies, and every state and district to support teachers and students in research-based programs so that every child has the opportunity to achieve to high standards.

The NSF's role is a continuum beginning with basic research on learning, research, and development in teacher education and teacher learning. NSF then seeks practical application of these research findings to help us better understand the role and impact of educational innovations and improvements. Finally, NSF implements new programs to evaluate how successfully they operate in a variety of contexts. The NSF's role includes not only the generation of knowledge and tools, but also support of activities that will build capacity and enhance the "improvement infrastructure" so that that infrastructure system eventually can provide on-going technical assistance to states and districts. The challenge for NSF is to create a better mechanism for integration and feedback across these roles. Research agendas must be informed by the needs from the field, in concert with the issues as understood by expert researchers. In turn, the results of research involve and feed back into the STEM education field to inform practice and into colleges and universities to inform the way that teachers are educated.

Outcome #1

Horizontal Coordination of STEM Education within and among States

Current Status:

Currently, the U.S. STEM education system is far from coordinated. The system is fractured and disjointed within school districts and from state to state, both from the perspective of students and teachers. Content standards and the sequence in which content is taught vary by state. In our geographically mobile society, both students and teachers are likely to relocate during their academic or professional life. Students who move from one location to another may miss exposure to a critical fundamental concept in one school system and never have the opportunity to master that concept.[5] Teachers face barriers to their movement between states in the form of teacher certification standards set independently by each state and the inability to carry over pension funds.[6]

Actions Needed:

A. Development and adoption of national STEM content standards
B. Linkage of student assessment with national STEM content standards
C. Alignment of the preparation and credentialing of STEM teachers with national content standards

A. Development and Adoption of National STEM Content Standards [7]

States must adopt a common national definition of "adequate" STEM education for our nation's students that are benchmarked against international standards and that are based on available research.[8]

National STEM Content Standards Action #1: Define and Periodically Review Core National STEM Education Content Standards[9]

Lead Entities – The National Academies, Professional Disciplinary Societies, and Professional Teaching Organizations

The National Academies, professional disciplinary societies, and professional teaching organizations, will be assigned the task of defining and periodically reviewing core national STEM content standards.[10] These research-based standards would build on pre-existing broad standards[11] and should be clear, specific, defined, and articulated between each grade-level.[12]

National STEM Content Standards Action #2: Provide Financial Incentives for State Adoption[13]

Lead Entities – Congress and the Department of Education

Congress should appropriate to the Department of Education funds to provide financial incentives to states that act consistently with national content standards. Other incentives may also be appropriate.

National STEM Content Standards Action #3: Provide Input to Inform Curriculum Development within the Framework of National Content Standards[14]

Lead Entity – The National Science Foundation (NSF)

NSF will devise coordinated initiatives through its current programs to continue the development of research-based, innovative tools, materials, and resources to promote K-12 STEM learning.

National STEM Content Standards Action #4: Provide Input to Inform STEM Curriculum Pathways within the Framework of National Content Standards[15]

Lead Entities – State P-20 Councils

State P-20 councils will leverage the partnership among their members – state and local education agencies, institutions of higher education, local businesses and industry, local STEM-related employers, and others – to inform STEM curriculum pathways and critical workforce skill requirements within the parameters of the national STEM content standards. This allows STEM curriculum pathways to be responsive to local needs and to career technical education goals and efforts.

B. Linkage of Student Assessment with National STEM Content Standards

Until recently, science has not been assessed under the No Child Left Behind Act (NCLB). As a result, science programs have been de-emphasized in many elementary schools as they focus on subjects, such as reading and mathematics, that are assessed under the legislation. Unless science is part of the evaluation, and counted as part of Adequate Yearly Progress (AYP), it will not receive the attention and resources required for every student to achieve basic science literacy and for highly motivated students to acquire the preparation needed for higher education in STEM fields. Because states do not currently share a common set of content standards upon which to base their assessments of student performance, their tests vary widely in the level of rigor and performance required. This allows for great variation in the quality of the education that students receive from state to state. Thus, comparisons and accomplishments are, at best, difficult to determine.

Student Assessment Action #1: Include Additional Measure of Science Learning for AYP[16]

Lead Entities – Congress and the Department of Education

Assessments of student performance under NCLB must be designed to reflect the knowledge, critical thinking skills, and problem-solving abilities required to meet real life challenges rather than the extent to which students have memorized the content required to pass the test. Science should be considered as part of AYP.[17]

Student Assessment Action #2: Develop National Content Standards for Assessment of Student Progress
Lead Entity – The National Assessment Governing Board (NAGB)[18]
The NAGB, in consultation with a wide range of experts, will be responsible for developing student assessments that derive from, and are aligned with, national content standards.[19]

Student Assessment Action #3: Provide Incentives to States Using National Content Standards for Assessment
Lead Entities – Congress and the Department of Education
Congress would appropriate funds to the Department of Education to provide incentives to states that voluntarily participate in standardized national testing that reflect national STEM content standards, problem-solving, and critical thinking skills. The National Assessment of Education Progress (NAEP) could act as a model for establishing these kinds of standards.[20]

Student Assessment Action #4: Participate Voluntarily in Standardized National Tests
Lead Entities –States
States should voluntarily participate in standardized national and international tests that reflect national STEM content standards.[21] Those states that participate would receive incentives.[22] States could collaborate in the development of tests, thus lowering the cost of test development.

C. Alignment of the Preparation and Credentialing of STEM Teachers with National Content Standards

STEM teachers should meet the requirements set by a national standard for STEM teacher quality. States would voluntarily align their credentialing of STEM teachers to meet national criteria. The value of this is two-fold. Such policies would ensure that teachers are prepared to teach the content specified in the national standards and facilitate teacher mobility within and among states.

Teacher Preparation Action #1: Create and Endorse National STEM Teacher Certification Standards
Lead Entity – National Institute for STEM Education Transformation (NISET)
NISET will coordinate with the teaching, policy, employment, and content communities to create and endorse national STEM teacher certification standards. NISET will organize all relevant groups in deriving a consensus as to how this would be implemented. These standards will facilitate the ability of teachers qualified in one state to move to another and continue a STEM teaching career and will clarify requirements for bringing STEM professionals from other occupations into the classroom.[23]

Teacher Preparation Action #2: Create and Endorse National STEM Teacher Certification Standards
Lead Entity – The National Science Foundation (NSF)
NSF would support research that can provide a foundation for determining and assessing teacher knowledge needed for effective STEM teaching at various stages of the career. They will also provide funding to develop and study examples of promising new models of fostering STEM teaching preparation and to create a mechanism whereby these new models can be replicated and brought to scale by other institutions.

Teacher Preparation Action #3: Provide Financial Incentives for National STEM Teacher Certification Standards
Lead Entities – Congress and the Department of Education
Congress will appropriate funds to the Department of Education to provide financial incentives to those states or districts that recognize national certification, as outlined in the above actions, and employ certified, qualified, and effective teachers of STEM.

Teacher Preparation Action #4: Provide Teacher Education Based on National STEM Content Standards[24]
Lead Entities – Institutions of Higher Education (IHEs)
IHEs will provide teacher education based on national STEM content standards. They must promote interactions both externally with other accredited institutions (particularly between community colleges and four-year colleges) and internally between the college of education and the colleges of arts and sciences, engineering, and technology, as appropriate, to prepare future STEM teachers. These interactions should promote high quality teacher education

focused on both content and the knowledge and skills associated with effective teaching. A key to this is the reworking of introductory courses to model pedagogy that motivates student interest in STEM fields. IHEs will utilize national STEM content standards and national STEM teacher qualification standards as guidance in developing their undergraduate curricula for STEM teacher education.

Teacher Preparation Action #5: Develop Policies Encouraging Institutions of Higher Education to Provide Teacher Education Based on National STEM Content Standards[25]

Lead Entities – Higher Education Accreditation Bodies and Disciplinary Societies

Both regional and specialized accreditation bodies and disciplinary societies must develop policies that require institutions of higher education to provide high quality teacher education that develops teacher competence and confidence in providing standards-based instruction.

Outcome #2

Vertical Alignment of STEM Education from Pre-K through Graduate Education

Current Status:

Due to the lack of alignment among STEM standards, curricula, student assessments, and professional development of teachers, core concepts are not always taught and understood at the elementary and middle school levels, limiting academic success at the high school level. Furthermore, high schools often offer curricula that are uninspiring, poorly aligned, outdated, lacking in rigor, and wrought with low expectations. Most high school curricula do not show pathways to the workforce or communicate the exciting nature of science and engineering. High school graduates often enter college unprepared for first-year coursework[26] or arrive at the workplace without the skills employers require.[27] Additionally, career technical education programs, which are independent of the traditional high school to college pathway, may hinder students from successfully matriculating into further degree programs. In addition, educators may leave teacher education programs lacking in content knowledge that correlates with the disciplines they will be asked to teach in the classroom. Teacher education programs may also fail to provide future teachers with a strong understanding of how students learn best and how knowledge connects to the real world.

Actions Needed:

A. Coordination between components of the STEM education system within states
B. Alignment of student learning across grade levels in pre-K-12
B. Alignment of post-high school student learning
C. Inclusion of informal science education institutions and other stakeholders in the understanding of STEM

A. Coordination between Components of the STEM Education System within States

Each state will either establish or continue to support a P-20 council to engage multiple stakeholders in improving STEM education in their state at the pre-K through graduate school levels.[28] The merit of P-20 councils has been outlined in several previous reports,[29] and a number of states already have established P-20 councils. These P-20 councils will work with, and communicate through, NISET and the NGA.

Coordination within States Action #1: Create and Empower State P-20 Councils[30]

Lead Entity – State Governors

Every state will create or continue to support a non-partisan and independent P-20 council to be led and empowered by the governor of that state. Each P-20 council will represent the combined input of the governor, legislature, state education agency, higher education system, local school boards, teacher associations, business and industry, chamber of commerce, private foundations, economic development initiatives, informal science education institutions, civic groups, and other professional organizations. P-20 councils will review the STEM education system in their respective states, and each will develop a strategy for vertically aligning this system. Additionally, the councils will develop a vision and set of measurable goals and timelines for implementation of STEM education reform and alignment. NISET will provide technical assistance and support to enable coordination among all the state P-20 councils.

B. Alignment of Student Learning across Grade Levels in pre-K-12

Although national science and technology standards do exist, they span grade levels and are not grade specific.[31] In contrast, mathematics has recently developed "focal points" for each grade, and since their release in 2006, they are under consideration by many states.[32] Each state builds their curricula based on these existing standards, but do not horizontally coordinate timelines with other states. This makes it difficult for publishers who have to ensure their materials match state standards in a number of states. As a consequence, textbooks are often excessively long and cover too much material at too little depth. Courses, like their textbooks, end up being a mile wide and an inch deep.

Alignment of Student Learning Action #1: Develop Curricular Content Standards, Benchmarks, and Assessments for Each Grade Level[33]

Lead Entity – State and Local Education Agencies (SEAs and LEAs) with P-20 Councils

Using the national content standards developed in Outcome #1 and in collaboration with state P-20 councils, SEAs and LEAs will develop a common set of curricular content standards and benchmarks defining what students must master at each grade level in order to advance to the next grade level. Content standards and benchmarks will be in place through 12th grade, emphasize a few core concepts in a discipline, and demonstrate how these ideas are cumulatively developed.[34]

Alignment of Student Learning Action #2: Align pre-K-12 STEM Benchmarks with Higher Education Requirements[35]

Lead Entities – Institutions of Higher Education (IHEs) with P-20 Councils

IHEs, including two- and four-year colleges and technical schools, will work with P-20 councils to align STEM learning, which will provide pathways for success in college and the workforce. As a result, the learning gap between what high school graduates should know, and what they do know, will narrow.[36]

Alignment of Student Learning Action #3: Engage Administrators in Professional Development that Encourages and Supports Alignment[37]

Lead Entities – Local Education Agencies (LEAs)

Local school leadership is imperative for aligning STEM curricula and providing the support and infrastructure necessary for its successful delivery in the classroom. School leaders at all levels must be engaged, including school board members, school superintendents, curriculum directors, principals, assistant principals, and department chairs. In particular, LEAs must provide professional development for principals on ways to identify, reward, support, and implement effective STEM teaching and learning.

Alignment of Student Learning Action #4: Provide STEM Learning Opportunities for Changing Student Demographics

Lead Entities - States

States will provide challenging STEM learning opportunities that ensure access, participation, and benefit for all students. States will create these learning opportunities to address the changing demographics and complexities of providing quality education for the current and future student population, which present different needs and require more robust programs. This may mean supplementing formal education for these students with appropriate informal STEM education settings or after-school programs.

Alignment of Student Learning Action #5: Provide Challenging STEM Educational Opportunities to Gifted Students

Lead Entities – States

States will provide challenging STEM educational opportunities to their most gifted and talented students by establishing STEM academies, schools within schools, or other special programs for this population of future innovators. Students with strong interest and aptitude in STEM subjects must be nurtured and provided connections to research opportunities.[38]

Alignment of Student Learning Action #6: Collaboration between Local Business and Industry and School Systems on STEM Workforce Skill Requirements[39]

Lead Entities - Local Education Agencies (LEAs) and P-20 Councils

LEAs will ensure that their students are equipped with the requirements and skill sets for STEM-related jobs and will collaborate with STEM-related businesses and industry through state P-20 councils and other mechanisms in order to gain the required technical expertise.[40] This cross-communication will promote student interest in STEM fields and the career technical education programs that are called for.

Alignment of Student Learning Action #7: Inform School Guidance Counselors and Teachers of Potential STEM Career Fields and Skill Requirements[40]

Lead Entities – P-20 Councils

P-20 councils must work with all stakeholders to provide middle school, high school, and college guidance counselors and teachers the tools and information necessary to inform students about STEM career opportunities and the occupational and foundational skills required for those jobs. In an era when nearly all jobs require some technical literacy, this information flow is essential to prepare all students for productive lives after high school graduation.[42]

Alignment of Student Learning Action #8: Strengthen Elementary School STEM Programs

Lead Entity – Local Education Agencies (LEAs)

As learning in elementary grades provides the foundation for future student interest and success in STEM fields and captures children's natural curiosity about the world around them, LEAs must support science, engineering, and technology curricula and opportunities for learning in addition to instruction in mathematics. The time allotted for this learning should be equivalent to that of other subjects.

C. Alignment of Post-High School Student Learning

Alignment of Post-High School Student Learning Action #1: Reduce Transfer Barriers among Institutions of Higher Education

Lead Entities –Institutions of Higher Education (IHEs) and P-20 Councils

IHEs within each state will strengthen articulation agreements among themselves in order for students to transfer STEM coursework more easily (and without losing credit) between institutions.[43] P-20 councils will work with higher education systems to improve and strengthen articulation agreements to ensure that courses taken at accredited institutions transfer and that students are given credit toward degrees for completing equivalent courses.[44]

Alignment of Post-High School Student Learning Action #2: Recognize Coursework at Community Colleges as Part of Teacher Preparation

Lead Entities – Institutions of Higher Education (IHEs)

IHEs, in collaboration with state P-20 councils, will develop articulation agreements that recognize associate degrees in teacher education at community colleges and allow the credits to transfer into schools or colleges of education at universities.[45]

Alignment of Post-High School Student Learning Action #3: Establish Expectations for STEM Curriculum at the 13-20 Education Levels

Lead Entities – Institutions of Higher Education, P-20 Councils, Professional Societies, and Higher Education Organizations

P-20 councils, professional societies, and higher education organizations will work with higher education systems to establish basic STEM literacy expectations for all college graduates.[46] College graduates must understand science as a way of thinking and knowing. Curricula must acknowledge that different student populations exist within colleges and universities, including the general student population, students majoring in STEM fields, and those preparing to be pre-K-12 teachers; however, all students need to have a basic understanding of how the world works within and across the inter-related STEM disciplines.

Alignment of Post-High School Student Learning Action #4: Develop Mechanism for Professional Development of Teachers Outside University Graduate Structures

Lead Entities – P-20 Councils and Local Education Agencies (LEAs)

P-20 councils need to endorse and facilitate a mechanism whereby credit for professional development in STEM content areas can be awarded outside university graduate structures by LEAs. This should include mechanisms that allow teachers on salary schedules credit for taking in-service or professional development courses at community colleges.[47]

D. Inclusion of Informal Science Education Institutions and Other Stakeholders in the Understanding of STEM

Informal science education institutions play a valuable role in increasing interest in and excitement about STEM fields. These institutions and other stakeholders need to be engaged and work cooperatively with the formal school environment to promote an understanding of STEM fields.[48]

Informal Science Education Action #1: Align Formal and Informal Science Education Institutions through Collaboration[49]

Lead Entities –Local Education Agencies (LEAs), Informal Science Education Institutions, and the National Science Foundation (NSF)

Through collaboration with LEAs and NSF, informal science education institutions will provide unique complementary experiences that enhance and reinforce formal school learning goals. Through direct activities with students, professional development opportunities for teachers, and online learning resources, these institutions provide invaluable supplements to support teaching and learning.[50]

Informal Science Education Action Item #2: Develop Programs to Provide Research Experiences for High School Students

Lead Entity – The National Science Foundation (NSF)

NSF will initiate a research and development program to build and study models to provide STEM research experiences for high school students.

Informal Science Education Action Item #3: Identify and Create a Database of Existing, Effective Informal Science Education Programs[51]

Lead Entity – National Institute for STEM Education Transformation (NISET) and the National Science Foundation (NSF)

NISET and NSF will identify museums, media, traveling laboratories, libraries, online resources, and interactive experiences that demonstrate evidence of effectiveness in STEM education of students, families, educators, and the public at large. NSF will support the compilation of a database of exemplary programs to use in developing additional programs. NISET will review and disseminate this database, thus including the work of these informal settings as part of the resources for the formal system.

Informal Science Education Action Item #4: Develop and Support Programs that Increase the Public Engagement with Science

Lead Entity – National Science Foundation (NSF)

NSF will continue to support research that helps the field understand the most effective models and approaches for learning in informal settings. NSF will also continue to support research on programs that foster the public understanding of STEM through the media and provide access to informal STEM institutions for underrepresented groups and those who are geographically isolated from informal science education institutions.

Informal Science Education Action Item #5: Provide Students with Real-World STEM Experiences

Lead Entities – Business and Industry

Business and industry should develop and provide mentoring, shadowing, and internship opportunities for students in grades 7-12.[52] In addition, co-ops and internships have proven to be effective in retaining STEM majors in STEM fields in colleges and universities.

Outcome #3

Attract, Prepare, Retain, and Support STEM Teachers and Educators

Current Status:

The strengthening of the STEM teaching profession requires a coordinated national effort to attract, prepare, and retain qualified and committed candidates to the teaching profession. The effectiveness of the STEM education system rests on the quality of the investment in and support of the nation's STEM teachers and educators. STEM educators in the United States must be viewed as a national resource that must be given thorough preparation prior to entering the classroom, adequate mentoring during the critical first few years in the classroom, opportunities for continual growth and enrichment of skills and knowledge, and proper support in order to be maximally effective STEM educators. Exemplary models of continued professional training and certification from other fields include medicine, architecture, and engineering. STEM educators require this level of professional development and training to reinstate American students at the forefront of global STEM education.

Actions Needed:

A. Recruitment and retention of qualified and committed candidates into STEM teaching careers
B. Implementation of continuous, standards-based, data-driven, and relevant STEM teacher professional development
C. Support of teachers to ensure effective teaching

A. Recruitment and Retention of Qualified and Committed Candidates into STEM Teaching Careers

A quarter million qualified K-12 mathematics and science teachers will be needed over the next decade.[53] Unfortunately, 48 percent of our nation's middle schools and 61 percent of our high schools have already reported difficulty in hiring qualified candidates for mathematics and science teaching positions.[54] This widening gulf requires immediate action, beginning with the recommendations listed below.

STEM Teacher Recruitment and Retention Action #1: Provide Tuition Assistance for Promising STEM Teachers[55]
Lead Entities – Congress and the States

Congress will appropriate increased funds to the states in order to provide tuition and/or financial assistance to college students majoring in STEM content areas who commit to becoming K-12 teachers.[56] Some states are already doing this with their own funds, and the Commission is supportive of this. With the rising cost of education in the United States, a student's ability to subsidize tuition costs may be a strong recruitment incentive.

STEM Teacher Recruitment and Retention Action #2: Subsidize Loan Forgiveness for STEM Teachers[57]
Lead Entity – The Department of Education

The Department of Education will provide loan forgiveness to students majoring in STEM content areas that are tied to service in teaching. This kind of program will attract graduating students who are considering employment opportunities and beginning the process of student loan repayment.

STEM Teacher Recruitment and Retention Action #3: Expand Funding for STEM Teacher Education[58]
Lead Entity – National Science Foundation (NSF)

NSF will expand efforts such as its Robert Noyce Scholarship program[59] that provides financial support to college students for post-graduation STEM teaching in public schools.[60]

STEM Teacher Recruitment and Retention Action #4: Provide Additional Income to STEM Teachers
Lead Entity – The Federal Government

Although teacher compensation is set by local school boards, the Federal Government must step to the plate and assist local education agencies in supplementing STEM teacher salaries. Although all teachers are valuable resources for the nation, market forces offer career opportunities with substantially higher salaries to professionals with STEM training than these professionals would receive in teaching careers.[61] The National Science Board has previously stated that, "To attract and retain precollege science and mathematics teachers, resources must be provided to compensate teachers of mathematics, science, and technology comparably to similarly trained S&E professionals in other economic sectors."[62]

STEM Teacher Recruitment and Retention Action #5: Advocate Competitive Teacher Salaries[63]
Lead Entities – State P-20 Councils

State P-20 councils would assist state and local education agencies in actively pursuing ways to increase STEM teacher incomes to competitive levels.[64] Various mechanisms to achieve this include developing partnerships with local business and industry, government research laboratories, and/or institutions of higher education in order to help teachers augment incomes through summer employment.

STEM Teacher Recruitment and Retention Action #6: Establish Pension Portability for Teachers

Lead Entity – National Governors Association (NGA)

The NGA is encouraged to work with states to coordinate a system that allows teacher pensions to be portable among states. Teacher mobility across states is greatly diminished by the teacher pension system.

STEM Teacher Recruitment and Retention Action #7: Institute STEM-Specific Teacher Induction Programs

Lead Entities – The Department of Education and the National Science Foundation (NSF)

The Department of Education and NSF will provide sustained funding for the development and implementation of subject matter teacher induction programs to support teachers during their first 2 years of teaching. These induction programs foster the professional community necessary for sustaining new teachers through mentoring, content specific professional development, and peer community development.

B. Implementation of Continuous, Standards-based, Data-driven and Relevant STEM Teacher Professional Development

The Federal Government, P-20 councils, states, LEAs, principals, local businesses, industry and other stakeholders should create professional development opportunities that deepen teachers' content knowledge, inquiry experiences, pedagogical skills, and understanding of instructional materials and their use in the classroom. Retaining high quality STEM teachers depends on facilitating access to opportunities for professional development and intellectual growth throughout their careers. Professional development must be sustained throughout teaching careers and support a professional learning community environment. It must incorporate available and emerging technologies, such as podcasting and e-mentoring, that can effectively deliver ongoing training in an asynchronous manner. Professional development must also provide teachers with access to STEM experts and updates on research findings. Providing teachers with a broad spectrum of professional development tools is critical to meeting the needs of the nation's STEM educators. Teachers should be prepared to teach to the standards, the curriculum for which they are responsible, and the student population in their classroom. They must be enabled to continually improve their practice.

Professional Development of Teachers Action #1: Fund Sustained Professional Development Programs

Lead Entity – The Department of Education and the National Science Foundation (NSF)

The Department of Education and NSF will provide funding for sustained professional development for teachers. NSF will provide funding for research, development, and implementation of focused teacher professional development models designed to enhance teachers' knowledge in ways that support students' STEM learning. NSF will also support the research and implementation needed to prepare these model approaches for going to scale. The Department of Education will provide funding for sustained professional development for teachers.

Professional Development of Teachers Action #2: Ensure STEM Teacher Access to Inquiry Based Pedagogy[64]

Lead Entity – National Science Foundation (NSF)

NSF needs to continue to develop, disseminate, and support research-based models, tools, and strategies to support development of content knowledge and content-specific teaching skills. Authentic experiences in science are needed for STEM teachers.

Professional Development of Teachers Action #3: Embed Professional Development during the School Day and Year[66]

Lead Entities – Local Education Agencies (LEAs) and School Principals

LEAs and school principals will support the development of professional learning communities and shared lesson planning time for teachers to improve teaching skills, the ability to evaluate student learning, and content knowledge in rapidly changing STEM fields.[67] Time for these activities would be included as part of the standard school year and school day.

Professional Development of Teachers Action #4: Support New Teachers through Appropriate Teaching Assignments and Mentoring

Lead Entities – Local Education Agencies (LEAs) and School Administrators

LEAs and school administrators have the responsibility to place new STEM educators into settings where they are most likely to succeed. State and local education agencies must implement policies to support mentoring of new teachers and eliminate the practice of assigning early career STEM teachers to the most challenging teaching situations. Likewise, administrators are encouraged to assign the most highly qualified and effective teachers to the most challenging students and environments. Additionally, school administrators must ensure that STEM teachers are not asked to teach non-STEM related classes.

Professional Development of Teachers Action #5: Provide Appropriate STEM Instructional Leadership and Infrastructure Support

Lead Entities – Local Education Agencies (LEAs)

LEAs will provide appropriate STEM instructional leadership and infrastructure support at all levels from the superintendent, curriculum director, principals, and assistant principals to the department chairs.

Professional Development of Teachers Action #6: Institute Mentoring Programs for Entering STEM Education Faculty at Institutions of Higher Education[68]

Lead Entities – Institutions of Higher Education (IHEs)

Colleges and universities should provide faculty development programs, including mentoring, for entering faculty who teach STEM courses. IHEs would reward faculty mentors for their involvement in the early career development of their colleagues as teachers. Pre-K-12 teachers who receive their education in colleges would benefit from having STEM content courses taught in such a way that their engagement with the subject matter is maximized and effective teaching strategies are modeled.

Professional Development of Teachers Action #7: Develop Programs to Link STEM Teachers with STEM Professionals

Lead Entity – National Science Foundation (NSF)

NSF must take the lead in developing programs that link classroom teachers with researchers in STEM fields and in STEM pedagogy and in studying these models to understand better the specific kinds of contributions such programs make to teacher effectiveness.

Professional Development of Teachers Action #8: Utilize Informal Science Education Institutions in Teacher Professional Development[69]

Lead Entities – Informal Science Education (ISE) Institutions

ISE institutions play a valuable role in continuing teacher professional development by broadening content knowledge, improving pedagogical skills, and providing real world, relevant experiences for the enhancement of teachers' content knowledge.

Professional Development of Teachers Action #9: Provide Professional Expertise to STEM Teachers[70]

Lead Entities – Professional Organizations

Professional STEM teaching organizations - such as the National Science Teachers Association (NSTA), National Council of Teachers of Mathematics (NCTM), National Association of Biology Teachers (NABT), and the International Technology Education Association (ITEA) - and disciplinary societies must provide continuing teacher professional development by using technology to supply "just in time" learning experiences. Organizations could use new technologies, such as e-mentoring, podcasts, etc., to reach teachers in all types of schools.

Professional Development of Teachers Action #10: Develop New Forms of Teacher Professional Development

Lead Entities – Institutions of Higher Education, Informal Science Education Institutions, Educational Research Organizations, the National Science Foundation, and Local Education Agencies

The entities named above will work cooperatively to research and develop new, innovative forms of teacher pre-service and in-service professional development based on science learning research to prepare teachers for real-world educational settings.

C. Support of Teachers to Ensure Effective Teaching

Teachers must be supported with the technology, teaching resources, mentoring, and planning time needed for effective teaching. Providing these resources to teachers is critical not only to their effectiveness, but also to their retention in the profession.

Teacher Support Action #1: Communicate Best Practices

Lead Entities – State and Local Education Agencies (SEAs and LEAs)

SEAs and LEAs will receive information from current research on the infrastructure required for quality STEM learning and best practices in STEM education. NISET could play a key role in the dissemination of this knowledge. National, state, and local associations would communicate these findings to Boards of Education, superintendents, principals, supervisors, and vice-principals through annual meetings of these groups.

Teacher Support Action #2: Provide Adequate Facilities and Infrastructure for STEM Learning

Lead Entities – State and Local Education Agencies (SEAs and LEAs)

SEAs and LEAs must provide adequate facilities and infrastructure (computers, laboratory equipment, and supplies) for STEM learning. This includes appropriate teacher planning time to implement curricula, teacher professional development, class and classroom size, safety equipment and training, and current technology. Students come to school technologically savvy, and operating STEM education classes without technology would guarantee failure.

Teacher Support Action #3: Provide Professional Development Opportunities to School Administrators

Lead Entities – National and State STEM Education Professional Organizations and Disciplinary Societies

National and state STEM education professional organizations and disciplinary societies must provide professional development opportunities for school boards, superintendents, and other administrators to identify, support, and encourage quality STEM education instruction. Annual meetings of these groups would provide an effective mechanism for providing professional development opportunities.

Teacher Support Action #4: Provide Professional Development Support Opportunities to Professional Support Providers

Lead Entities – State and Local Education Agencies (SEAs and LEAs), the Department of Education, the National Science Foundation (NSF), Informal Science Education Institutions, and Educational Research Organizations

The entities above would cooperatively create ongoing professional development opportunities and a learning community for the staff who are responsible for professional development in SEAs and LEAs.

Teacher Support Action #5: Provide Special Training in the Teaching of STEM Courses

Lead Entities – Institutions of Higher Education

Training of teachers rarely includes the very special requirements of how to teach science. Teachers should know that science comes in two parts: a content part and a process part. The blending of these is of overriding importance towards the STEM education objective. The training of STEM teachers must include an understanding of what is science, what is engineering, what is mathematics, and how they interact. The training of STEM teachers must include the sense that the world we live in is permeated by the science, mathematics, and engineering that converts concepts into the artifacts of our civilization and that create the sense of pleasure, joy, excitement, and empowerment, which drives the scientists as humans.

Unfinished Business

This Commission focused on many issues relevant to the transformation of STEM education and recommended specific mechanisms and actions to support this transformation. However, there are additional important educational issues that state and local councils will need to address. Outlined below are some of the most pressing of these issues. We especially look to the new national coordinating entity, NISET, to continue the transformations suggested here.

Special Populations

The Commission identified the need to address the major challenges subsumed under the goal of providing quality education to *all students*: raising the floor of expectations, access to quality programs, and removing the ceiling that limits the potential for growth and achievement for students with the greatest interests and aptitude for STEM. Addressing the needs of students with disabilities, English language learners, students from low socio-economic backgrounds, as well as students who have completed high school but who are not prepared for college or the workforce, is a challenge the entire community must acknowledge and accept. These unique student populations often come from impoverished families and attend racially or ethnically segregated and substandard schools. They need to be provided with opportunities and resources for success, including opportunities for STEM education and careers. Making use of the entire talent pool is a priority issue for STEM education since demographics will require major contributions to the workforce from those groups who have been "left behind." We are obligated to provide a level of education that will permit every young person to reach her/his potential.

It is also in our best interest to nurture our most talented students. Major revolutions of the 21st century - globalization and technology - require that we foster a culture of innovation and the support the next generation of innovators who will help shape our future. NISET would be expected to play a role in the organization of a national program for gifted education.

We can and must address both the skills gap and the performance gap. We cannot pit equity and access against competitiveness and innovation. The Nation can and must advance both.

Early Childhood Education (ECE)

A strong movement has emerged among the states for support of universal early childhood education. Fueled by changing family dynamics and research on brain development, states are responding to demands for such programs in support of promoting school readiness and hopes of greater success in K-12 education. As this movement grows with strong Federal support, more state investment, and positive outcomes for children, NISET and NGA would be expected to create new action plans that more prominently include STEM education as a component of ECE.

Learning about Learning

As we learn more about pedagogy, opportunities will emerge to inform the work of the teacher in the classroom and the faculty member in the laboratory and lecture hall. Especially important is the need to consider how best to support and assess conceptual understanding of STEM concepts, how the formal and informal systems for learning work together over a lifetime, and how to close the so-called "achievement gap."

Time for Schooling

It has been established that only about fifty per cent of the school day in American schools is devoted to learning. We have a shorter school day and school year than most industrialized nations. The long summer holiday has a negative affect on the continuity that is required in learning, especially for our most disadvantaged children, supporting loss of ground in their learning. Our present school calendar was set by a farming nation, and many educators believe it is time to change. Alternatives to this calendar have been adopted in many places that may act as test laboratories as districts consider other arrangements that can provide more time for learning. Here, too, the NISET mechanism with state collaboration would provide a forum to develop consensus on the issue of "time to learn."

This issue calls for thoughtful consideration of the use of non-school hours for students, such as the development and availability of quality informal programs that complement formal learning.

Time for Teachers

While the action plan addresses issues of continuous professional development of teachers, it does not address the need to create the time and circumstances for teachers to communicate with one another (i.e., mathematics and science teachers, chemistry and physics teachers, science and technology teachers and larger groups that include language, the arts and social sciences) to shore up the deep interconnections among the disciplines that underlie education. Time is also needed to support the interaction with local community college and university faculty, business, and political leaders as well as with parents and the larger community.

Curricula Matters

Research-based curricula are needed to support the standards that emerge. Many areas of study are not currently offered in most schools, such as those that focus on the nature of technology and engineering, applications of mathematics and science to these areas, or issues related to societal impact of science and technology. Local education agencies are unlikely to accept the notion of a single national curriculum. This Commission is not advocating a single national curriculum. We are advocates for national standards and believe that it may be possible to offer several high quality choices. National support is needed to create these standards. In all cases, there is the need to reduce the number and increase the depth of topics covered and to create seamless transitions, i.e., topics in middle school following smoothly from primary school and preparing students for study in high school and beyond.

Technology in Education

Technology has permeated much of our lives, but it oftentimes stops at the schoolhouse door. Technology has an important role to play in the transformation of STEM education at all levels, but the investments must be made to experiment, innovate and disseminate. Many of our students are growing up in a technology-rich environment that is radically different from the experiences of their teachers and those responsible for governance of schools. All citizens will need the technology to confront the world of the 21st century. Students are emerging from our 20th century classrooms knowing how to go online, explore Web territories unknown to their teachers and to those who educate teachers. They call it Web 2.0. Students are learning from blogs and wikis and podcasts. They connect to knowledge content but also to people, ideas, and conversations. A major task for STEM education transformation is to design the 21st century classroom and 21st century learning experiences, and to prepare teachers for the altered culture of Internet-era students. On the whole, there is a need to focus much more on understanding the students: their interests and skills, their motivations and aspirations. This would allow us to build on the strengths that students bring to support their further learning and development.

The greatest promise of technology is its ability to create new environments for learning. Students explore virtual worlds through guided inquiry and experimentation. Computers are increasingly used to enhance hands-on experimentation by using real-time data acquisition and analysis with probes and probe-ware. Technology supports new forms of student collaboration within the classroom and across the world. These collaborations can enrich the curriculum, link to informal learners, stimulate thought, and prepare students for the kinds of collaborations that are integral to science, business, and government.

Appropriate technology not only delivers new, collaborative learning materials, it can provide guidance and embedded assessments that yield fine detail about student effort and progress at home, at school, and in informal settings. Data from learners' actions can be used by educators to alter the learning experience and use the ideas of Universal Design for Learning to better match the interests and needs of students. Finally, data from learners create unprecedented research opportunities that allow us to track large numbers of learners and understand details of their ideas and learning patterns. Research based on such data could help in the design of new generations of materials and curricula.

Technology can revolutionize teacher professional development. A mix of online courses, video case studies, discussions, and technological resources teachers can use with their students can create experiences for pre-service and in-service teachers that can increase their students' performance.

There are many technological innovations waiting to be explored that could improve STEM education, but there has been insufficient funding to develop them. As computers become less expensive, more portable, and more easily networked, the technology is far outpacing the ability of education to exploit its promise. It is not necessary to wait for the next generation of technology, however. There is already an adequate base of research and design experience to generate significant educational gains through more extensive use of today's technology. Current technologies need to be fully exploited in a new round of curriculum materials for STEM education. These materials can teach the current curriculum better because of technology. Advances in technology also make it possible to strengthen the curriculum with new content that can be taught earlier.

Higher Education

Post-secondary education in the United States includes many components from technical schools and community colleges to research universities: public, private, proprietary, single sex and minority-serving, liberal arts and technical institutes. The variety is staggering. All contribute in different ways to support the advancement and dissemination of knowledge and the development of skills necessary for citizenship, economic growth, and prosperity. Increasing numbers of our citizens take advantage of these places for learning. The knowledge-based economy that emerged over the 20th century will mean that, for an increasing number of future workers, 21st century employment will require some level of education beyond high school. The form and depth of that education will be critical to providing them with the level of knowledge and skills they will need to continue to learn for a lifetime.

A notable failure of higher education is the very low level of science and mathematics required of those who undertake study outside of STEM fields. A troubling example is the state of science and mathematics knowledge of primary school teachers. A lack of confidence is translated into an unwillingness and/or inability to teach these subjects. Under-prepared teachers may approach mathematics and science lessons with a palpable insecurity that their students can sense.

The traditional science requirement of a semester of "Rocks for Jocks" or "Physics for Poets" will no longer serve to produce the kind of responsible citizenship that the Nation needs. It is also fair to complain that most colleges continue to graduate teachers who are woefully unprepared or under-prepared to teach mathematics and science.

A 21st century college graduate should be capable of citizenship in our democratic society by active participation in decisions made on the national level as well as in the family and the community. We need standards of what such a graduate should know – a national consensus on the range, the rigor, and the duration of a 21st century science requirement. National input to such standards could be formulated by the National Academies and AAAS, perhaps organized by NISET. Whereas these would clearly not be prescriptive, the national attention to a discussion of the "STEM knowledge requirements of citizenship" can have a huge influence on the colleges and universities of the nation. It is quite clear that students need content knowledge related to the physical, biological, social, behavioral, economic, and earth sciences, as well as knowledge of technology and "process" – how did we find out what we know? how do we answer questions in the future? and how do we manage to survive, prosper and enjoy? In the age of the Internet and 24/7 information, students must have tools for discernment; we must give them the tools they need to make critical judgments of information, from Wikipedia, blogs, Britannica, Fox News, or *The New York Times*.

Another problem within institutions of higher education is the hole in the STEM pipeline that opens up after the first year of college. Even high school graduates who have demonstrated interest in and dedication to science through having invested heavily in AP mathematics and science courses and science fairs and clubs leave STEM majors. Such an exodus, often after their experience with poorly taught introductory courses in physics or chemistry in their freshman year, represents a disastrous loss of STEM talent and failure to maintain the flame that led these students initially to declare as STEM majors upon completing high school.

Dramatic counterexamples are emerging, however, from many liberal arts institutions, from a number of minority-serving institutions, women's colleges and community colleges, as well as from universities where powerful research results are emerging on the teaching of science from leaders such as Lillian McDermott, Eric Mazur, Carl Wieman, and others.

Sidebar Suggestions

A Science Way of Thinking

A frequently debated issue in STEM education is "How much science should non-science students know?" An easy response is: they should have acquired a "science way of thinking."

This seemingly exotic concept of "A Science Way of Thinking" was stressed in the 1930's by famed U.S. educator, John Dewey. Dewey urged scientists to convey the science way of thinking to all phases of education as a "SUPREME INTELLECTUAL OBLIGATION." Although this includes critical thinking, curiosity, skepticism, and verification by observation and measurement, its deeper meaning has to do with the sense of wonder and awe that emerges from the student's gradual realization that the natural world is orderly and comprehensible. The overarching laws of science enable predictions: sunrise, weather, and the hour and day of the return of Halley's Comet in 2061. The appreciation and respect implied here are tragically missing from our science classrooms.

The body of knowledge generally termed "scientific stuff" is the content of science, what we know about how the world works. There is also the process of science, the observation and measurements of phenomena, the slow conversion of phenomena to knowledge via the process of testing and rational thinking.

The fitting together of pieces of knowledge into a coherent framework is the art of science. This process evolves so that larger and larger elements in the domain are included. This knowledge, a "theory," tentative until disproved by fact or, by surviving extensive and repeated tests, is accepted as a law. Unfortunately, scientists still call it a theory.

Essential to the process of science is the storytelling. Who did what and why and how do we come to know? Science is a humane and accessible indulgence, carried out by humans called scientists. What they say they are doing, in addition to their personal and cultural perspectives, is the process of science.

But the teacher brews the wonder, colors the learning, and resonates with the students so that they exclaim, "Yes! This is the way it works." The chart of the periodic table glows with meaning. DNA, a once secret code, is now a user's manual for human genetics. Gravitation guides planets, comets, and falling apples. Superconductivity, so neatly demonstrated in classrooms labs, is a key to technologies that bring comfort and wealth: magnets for MRI, filters for city water systems, and rings for giant atom smashers. "How else, class, can we use this invention?" The tragedy is the rarity of this epiphany. Yet the "Science Way of Thinking" encapsulates the goal of science education for non-science students and scientists alike!

Employment, citizenship, parenthood, leisure will all be profoundly influenced by 21st century developments, making Dewey's quest for education, built on a science way of thinking, ever more crucial.

STEM Education Reform in a "Liberal Arts" World

A recent poll conducted by the American Council of Education underscored the weakness of the public's grasp of why education in the sciences and mathematics is crucial for non-science students.[71] This raises the issue of the age-old conflict between the role of science and that of the other liberal arts subjects. Yes, the public will accept a 3-year science requirement in high schools – but just barely. Yes, some (but not too much) science should be taught in college to non-science majors. Most colleges can still get away with a one semester "Rocks for Jocks" requirement to educate its graduates.

We need to look at STEM as an arrowhead of educational reform at all levels, but most especially in high schools and colleges. The 21st century STEM workforce must be communicators, must have a grasp of history and geography (must <u>easily</u> be able to find India on a map!), must be critical thinkers, and must understand in general terms how our government works. The vast influence of globalization as described in Tom Friedman's book, <u>The World is Flat</u>, stresses the importance of a liberal arts education that includes STEM fields.

The U.S. tradition of general education to grade level 14 is completely appropriate for the new century. This means that <u>all</u> students - high school graduates, students in higher education through grade 14 - must have a reasonable grasp of how science and technology work. Why? We live in a world where it is difficult to think of any employment that is not tinged by some scientific or technological issue or any area of life unaffected by them.

Law and science continuously intersect: patents, liability, international agreements, and Katrina and its lawsuits are a few issues. Healthcare and diagnostics are totally entwined with medical science. Understanding the dynamics of global climate change emerges from software that must take into account ocean solubility, atmospheric chemistry, reflectivity of ice and snow, solar radiation, and many other factors. National defense involves nuclear science, properties of toxic gases, communications technology, and radar and missile technology. Software is the third greatest employer in industry and includes the World Wide Web, Internet, laptops, and main frames. This merges into the chip industry and the micro miniaturization of electronics. To be ignorant of, for example, atoms, molecules, electrons, and energy, is to try to live in a country with no knowledge of the language spoken and no interest in learning it.

Some day all graduates of good colleges will have taken 2 years of laboratory science. However, the long-term success of STEM education reform will depend on a public grasp of, and support for, a grounding in STEM education for all students.

Television Interstitials

When asked to draw a picture of a scientist, most young people create an image of an older, eccentric-looking man. However, opportunities abound to show a very different picture – young men and young women who are bright, articulate, and driven by a love of science and technology, starring in a science fair near you! We must use the vision that these students provide to offer a different image of science, a different image of scientists, and an expanded image of teens. Our schools are blessed with young scientists – the students who star in science fairs – who are articulate and driven by a love of science and technology. Science fairs offer a vision of the excitement, drama, competition, and enthusiasm about science that are so seldom seen or imagined by the public. We need to offer the public a fresh view of the nature of science, how it works, and how deeply it enriches our culture. TV networks can make available creative interstitials: ninety seconds here, two minutes there, for these young ambassadors of science to talk about their projects. These spots could appear three or four times a day, three or four days a week. Science fairs can easily supply these short videos, filmed during the events. Many hundreds of such gems can be made available. The kids would be thrilled, the networks would be fulfilling their legal and moral commitments, and the public would be charmed and be made aware of the nature of science, how it works, and how deeply it enriches our culture.

Endnotes

[1] The House Committee on Appropriations report, which accompanied the FY2006 Science, State, Justice, Commerce and Related Agencies Appropriations Bill, included report language endorsing the establishment of the STEM Commission. The report states, "The Committee understands that the Board has taken steps to establish a commission to make recommendations for NSF and Federal Government action to achieve measurable improvements in the Nation's science education at all levels. The Committee strongly endorses this effort." This report language was adopted in the final conference report for the Bill. Conference Committee, *Conference Report; Making Appropriations for Science, the Departments of State, Justice, and Commerce, and Related Agencies for the Fiscal Year Ending September 30, 2006, and for Other Purposes*, 109th Cong., 1st sess., 2005, H. Rep. 272, 184.

[2] The National Defense Education Act (NDEA) was passed in 1958 to aid science education in the U.S. in response to the launch of Sputnik by the Soviet Union. The NDEA was instituted primarily to stimulate the advancement of education in the elementary and secondary levels in science, mathematics, and modern foreign languages; but it has also provided aid in other areas, including technical education, and English as a second language. Of even greater significance, however, the act opened the way for future legislation that redefined many of the relationships between the Federal government and the education community. More information can be found at: *http://www.dod.mil/ddre/text/t_ndea.html*

[3] The National Science and Technology Council (NSTC) was established by Executive Order in 1993. This Cabinet-level Council is the principal means within the executive branch to coordinate science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in a broad array of areas. The Council prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of the NSTC is organized under four primary committees; Science, Technology, Environment and Natural Resources and Homeland and National Security. More information can be found at *http://www.ostp.gov/nstc/index.html*.

[4] The Subcommittee on Education and Workforce Development is part of the NSTC Committee on Science.

[5] Also recommended in National Science Board, *Preparing Our Children: Math and Science Education in the National Interest* (Arlington, VA: 1999).

[6] This problem is discussed at length in a series of strategy briefs developed by State Higher Education Executive Officers (SHEEO) developed under the project *Enhancing the Teaching Profession: The Importance of Mobility to Recruitment and Retention* which was supported under a grant by the Ford Foundation. The three reports produced under this project are *Improving Pension Portability for K-12 Teachers,* Sandra S. Ruppert, (Denver, CO: Educational Systems Research, February, 2001) *http://www.sheeo.org/quality/mobility/pension.PDF*; *Teacher Recruitment, Staffing Classrooms with Quality Teachers*, Eric Hirsch, (Denver, CO: National Conference of State Legislators, February, 2001). *http://www.sheeo.org/quality/mobility/recruitment.PDF*; and *Solving Teacher Shortages Through License Reciprocity*, Bridget Curran, Camille Abrahams, and Theresa Clarke, (Denver, CO: National Governors Association Center for Best Practices. February, 2001). *http://www.sheeo.org/quality/mobility/reciprocity.PDF*

[7] An element of this recommendation is included in a portion of H.R. 325, the *SPEAK Act*, which requires the Secretary of Education to create the American Standards Incentive Fund to award grants to states that adopt math and science standards and then align those standards with their teacher certification and professional development standards. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/D?c110:1:./temp/~c110eyIIwF*: (accessed March 15, 2007). A model for voluntary education content standards is defined and explained in Finn, Jr., C.E., Julian, L., Petrilli, M.J. *To Dream the Impossible Dream: Four Approaches to National Standards and Tests for America's Schools*, Thomas B. Fordham Foundation, p.22-27 (August, 2006).

[8] The Third International Mathematics and Science Study (TIMSS) observed that mathematics and science curricula in U.S. high schools lack coherence, depth, and continuity and cover too many topics in a superficial way. Standards must emphasize depth of understanding over exhaustive coverage of content. National Center for Education Statistics, "Third International Mathematics and Science Study," *Institute of Education Sciences* (Washington, DC: U.S. Department of Education, 2003), *http://nces.ed.gov/timss/index.asp* (accessed March 15, 2007).

[9] Also recommended in American Association for the Advancement of Science, *A System of Solutions: Every School, Every Student* (Washington, DC: American Association for the Advancement of Science, 2005), Carnegie Commission on Science, Technology, and Government, *In the National Interest: The Federal Government in the Reform of K-12 Math and Science Education* (New York: 1991).

[10] A current piece of legislation, H.R. 325 (and its Senate companion bill, S. 224), the *SPEAK Act*, assigns this responsibility to the National Assessment Governing Board. These bills task the Board with creating or adopting voluntary math and science education content standards for grades K-12 (the standards should reflect knowledge needed to enter college or the workforce). Additionally, the bills require the Secretary of Education to establish the American Standards Incentive fund to award competitive four-year grants to states which agree to adopt such standards as the core of their own math and science standards and align these standards with their teacher certification and professional development requirements. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/C?c110:./temp/~c110agnnE4* (accessed March 15, 2007).

[11] These grade-specific standards could build upon pre-existing standards such as: National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics* (Reston, VA: NCTM, 2000); International Technology Education Association, *Standards for Technological Literacy* (Reston, VA: ITEA, 2000); American Association for the Advancement of Science, *Benchmarks for Science Literacy* (Oxford Unity Press, 1993); National Research Council, *National Science Education Standards* (Washington, DCL National Academy Press, 1996); and Douglas Gorham, Pam Newberry, and Theodore Bickart, "Engineering accreditation and Standards for Technological Literacy," *Journal of Engineering Education* 92 (2003).

[12] The Third International Mathematics and Science Study (TIMSS) observed that mathematics and science curricula in U.S. high schools lack coherence, depth, and continuity and cover too many topics in a superficial way. Standards must emphasize depth of understanding over exhaustive coverage of content. National Center for Education Statistics, "Third International Mathematics and Science Study," *Institute of Education Sciences* (Washington, DC: U.S. Department of Education, 2003), *http://nces.ed.gov/timss/index.asp* (accessed March 15, 2007).

[13] Also recommended in Carnegie Commission on Science, Technology, and Government, *In the National Interest: the Federal Government in the Reform of K-12 Math and Science Education* (New York: 1991).

[14] Also recommended in Carnegie Commission on Science, Technology, and Government, *In the National Interest: the Federal Government in the Reform of K-12 Math and Science Education* (New York: 1991).

[15] Also recommended in Carnegie Commission on Science, Technology, and Government, *In the National Interest: the Federal Government in the Reform of K-12 Math and Science Education* (New York: 1991), and The National Science Board, *Preparing Our Children: Math and Science Education in the National Interest*. (Arlington, VA: National Science Foundation, 1999.)

[16] Also recommended in the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 199*5 (Arlington, VA: National Science Foundation, 1983); The National Science Board, *America's Pressing Challenge - Building a Stronger Foundation: A Companion to Science and Engineering Indicators*, NSB-06-02 (Washington DC: Government Printing Office, 2006); and the Domestic Policy Council of the Office of Science and Technology Policy. *America's Competitiveness Initiative; Leading the World in Innovation* (Washington DC: Government Printing Office, 2006).

[17] Using such metrics as an added measure of AYP is reflected in H.R. 35, the *Science Accountability Act of 2007*. This act would amend the Elementary and Secondary Education Act of 1965 to require the use of science assessments in the calculation of adequate yearly progress. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/z?c110:H.R.35*: (accessed March 15, 2007).

[18] The National Assessment Governing Board (NAGB), appointed by the Secretary of Education but independent of the Department, sets policy for the National Assessment Education Program (NAEP) and is responsible for developing the framework and test specifications that serve as the blueprint for the assessments. The NAGB is a bipartisan group whose members include governors, state legislators, local and state school officials, educators, business representatives, and members of the general public. Congress created the 26-member Governing Board in 1988.

[19] A current piece of legislation, H.R. 325 (and its Senate companion bill, S. 224), the *SPEAK Act*, assigns this responsibility to the National Assessment Governing Board. These bills task the Board with creating or adopting voluntary math and science education content standards for grades K-12 (the standards should reflect knowledge needed to enter college or the workforce). Additionally, the bills require the Secretary of Education to establish the American Standards Incentive fund to award competitive four-year grants to states which agree to adopt such standards as the core of their own math and science standards and align these standards with their teacher certification and professional development requirements. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/C?c110:./temp/~c110agnnE4* (accessed March 15, 2007).

[20] An element of this recommendation is included in a portion of H.R. 325, the *SPEAK Act*, which requires the Secretary of Education to create the American Standards Incentive Fund to award grants to states that adopt math and science standards and then align those standards with their teacher certification and professional development standards. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/D?c110:1:./temp/~c110eyIIwF*: (accessed March 15, 2007). NAEP is the only nationally representative and continuing assessment of what America's students know and can do in various subject areas. Since 1969, assessments have been conducted periodically in reading, mathematics, science, writing, U.S. history, civics, geography and the arts. National NAEP reports information for the nation and specific geographic regions of the country. It includes students drawn from both public and nonpublic schools and reports results for student achievement at grades 4, 8, and 12. More information can be found by going to: *http://nces.ed.gov/nationsreportcard*

[21] Also recommended in the National Governors Association and Council on Competitiveness, *Innovation America: A Partnership* (Washington, DC: National Governors Association, February 24, 2007). Page 9. *http://www.nga.org/Files/pdf/0702INNOVATIONPARTNERSHIP.PDF*

[22] An element of this recommendation is included in a portion of H.R. 325, the *SPEAK Act*. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/D?c110:1:./temp/~c110eyIIwF*: (accessed March 15, 2007).

[23] Interstate Agreement (2005-2010) by the National Association of State Directors of Teacher Education and Certification (NASDTEC). This agreement has 41 state participants as well as the District of Columbia. Its purpose is to establish a process under which a person prepared or certified in one Member state may obtain a certificate from another Member state. *http://www.nasdtec.org/docs/NIC_2005-2010.doc*; and Problem discussed in a paper presented at the STEM Institute for Alternative Certification of Teachers meeting, Online Science Methods for Lateral Entry Science Teachers, William R. Veal, Dorothy Mebane and Keri Randolph (Arlington, VA: Science, Technology Engineering and Math Education Institute for Alternative Certification of Teachers, May 5-7, 2006). *http://www.stemtec.org/act/PAPERS/William Veal.doc*.

[24] Also recommended in National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995* (Arlington, VA: National Science Foundation, 1983); National Science Board, *Preparing Our Children: Math and Science Education in the National Interest* (Arlington, VA: National Science Foundation, 1999); Building Engineering and Science Talent, *A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics* (Washington, DC: BEST, 2004); and Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education* (Washington, DC: Business-Higher Education Forum, January 2005).

[25] Also recommended in National Science Board, *Preparing Our Children: Math and Science Education in the National Interest* (Arlington, VA: National Science Foundation, 1999).

[26] "One-third of our high school graduates are not prepared to enter postsecondary education or the workforce." Council of Chief State School Officers, *Mathematics and Science Education Task Force, Report and Recommendations* (June 2006 through October 2006), p. 1.

[27] Also recommended in National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: 2000).

[28] Examples of these regional organizations are mentioned in the "P-16 Collaboration in the States" by the Education Commission of the States (ECS). Updated June 2006. Denver, CO. *http://www.ecs.org/clearinghouse/69/26/6926.pdf*

[29] Also recommended and discussed in the National Governors Association and Council on Competitiveness, *Innovation America: A Partnership*. (Washington, DC: National Governors Association, February 24, 2007).

[30] Also recommended in National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995* (Arlington, VA: National Science Foundation, 1983); The National Science Board, America's Pressing Challenge - Building a Stronger Foundation: *A Companion to Science and Engineering Indicators*, NSB-06-02 (Washington DC: Government Printing Office, 2006); the Domestic Policy Council of the Office of Science and Technology Policy. *America's Competitiveness Initiative; Leading the World in Innovation* (Washington DC: Government Printing Office, 2006.); National Science Board, *Preparing Our Children: Math and Science Education in the National Interest* (Arlington, VA: National Science Foundation, 1999); American Association for the Advancement of Science, *A System of Solutions: Every School, Every Student* (Washington, DC: American Association for the Advancement of Science, 2005); Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education* (Washington, DC: Business-Higher Education Forum, January 2005); and National Governors Association and Council on Competitiveness, *Innovation America: A Partnership* (Washington, DC: National Governors Association, February 24, 2007) page 5,7,8.

[31] These grade-specific standards could build upon pre-existing standards such as; International Technology Education Association, *Standards for Technological Literacy* (Reston, VA: ITEA, 2000); American Association for the Advancement of Science, *Benchmarks for Science Literacy* (Oxford Unity Press, 1993); and National Research Council, *National Science Education Standards* (Washington, DCL National Academy Press, 1996).

[32] National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics* (Reston, VA: NCTM, 2000).

[33] Also recommended in National Science Board, *Preparing Our Children: Math and Science Education in the National Interest* (Arlington, VA: National Science Foundation, 1999) and Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education* (Washington, DC: Business-Higher Education Forum, January 2005).

[34] These grade-specific standards could build upon pre-existing standards such as: National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics* (Reston, VA: NCTM, 2000).

[35] Also recommended in Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education* (Washington, DC: 2005).

[36] According to the Alliance for Excellent Education, the nation is losing $3.7 billion a year due to insufficient preparation for college and the workforce. Students are not learning the basic skills to move forward on these two trajectories. That figure includes $1.4 billion which is spent on remedial education for recent high school graduates. The additional costs account for the public resources that support remedial coursework at two-year institutions, the cost of tuition, and the cost of lost time and wages. Alliance for Excellent Education, *Inadequate High Schools and Community Colleges Remediation* (Washington DC: 2006). *http://www.nam.org/s_nam/sec.asp?CID=86&DID=84* (accessed 3 May 2007).

[37] Also recommended in National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: U.S. Department of Education, 2000).

[38] Currently special schools exist in a numbers of states. Examples include the Illinois Mathematics and Science Academy in Illinois (*http://www.imsa.edu/*), North Carolina School of Science and Math in North Carolina (*http://www.ncssm.edu/*), and the Bronx High School of Science, (*http://www.bxscience.edu/about.jsp*).

[39] National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All*

American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995 (Arlington, VA: National Science Foundation, 1983).

[40] An example of such a relationship between the STEM education community and industry is illustrated in a provision proposed in H.R. 37, the *National Science Education Tax Incentive for Business Act of 2007.* This bill amends the Internal Revenue Code to allow a general business tax credit for contributions of property or services to elementary and secondary schools and for teacher training to promote instruction in STEM fields. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/C?c110:./temp/~c110VwjHj0* (accessed March 15, 2007).

[41] Also recommended in National Science Board, "America's Pressing Challenge – Building a Stronger Foundation," *Companion to Science and Engineering Indicators 2006* (Arlington, VA: National Science Foundation, 2006).

[42] The U.S. Department of Labor projects that new jobs requiring science, engineering and technical training will increase by 51% between 1998 and 2008; a rate of growth that is roughly four times higher than average job growth nationally. Opstal, Debra van and Michael E. Porter. *U.S. Competitiveness 2001: Strengths, Vulnerabilities, and Long-Term Priorities.* (Washington DC: Council on Competitiveness, January 2001). *http://www.compete.org/pdf/competitiveness2001.pdf*

[43] Also recommended in *Getting it Done: Ten Steps to a State Action Agenda*, *A Guidebook of Promising State and Local Practices*, National Governors Association Center for Best Practices, (Washington, DC: National Governors Association, March, 2005). Pages 19-21. *http://www.nga.org/portal/site/nga/menuitem.9123e83a1f6786440ddcbeeb501010a0/?vgnextoid=0517a32889da2010VgnVCM1000001a01010aRCRD* Currently, Florida (*http://scns.fldoe.org/scns/public/pb_index.jsp*), Texas (*http://www.tccns.org/ccn/phil.htm*), Georgia (*http://www.usg.edu/academics/handbook/section2/2.04/2.04.05.phtml*), California (*http://www.curriculum.cc.ca.us/Curriculum/Resources/CAN_Guide.htm*), Colorado (*http://www.cccs.edu/cccns/Home.html*) and Oregon (*http://oregonstate.edu/ap/curriculum/common.html*) each employ a common course numbering system.

[44] For an example, look at the Ohio Articulation and Transfer Policy, *http://regents.ohio.gov/transfer/policy/index.php.* This policy was created to improve transfer student mobility and includes provisions to maximize the award and application of credit for prior learning and equitable treatment for transfer students. Ohio State University has completed three transfer agreements with three northeast Ohio community colleges and with the Columbus State Community College.

[45] According to the American Association of Community Colleges, 20 percent of teachers began their post-secondary schooling at community colleges, and 4 out of 10 teachers completed math and science courses at community colleges. American Association of Community Colleges, *Teaching by Choice; Community College Science and Mathematics Preparation of K-12 Education* (American Association of Community Colleges: Washington, DC, 2004).

[46] Examples include the Accreditation Board for Engineering and Technology, *http://www.abet.org/* and the National Association of State Universities and Land Grant Colleges (NALSUGC), *http://www.nasulgc.org/*

[47] Currently in some cases teachers are not given credit for professional development for STEM content courses at community colleges due to their low course numbers.

[48] National Science Teachers Association Position Statement of Informal Science Education. NSTA recognizes and encourages the development of sustained links between the informal institutions and schools. *http://www.nsta.org/about/positions/informal.aspx*

[49] Also recommended in National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995* (Arlington, VA: National Science Foundation, 1983).

[50] Currently, by the time children reach the age of 18, they spend almost four times the amount of time in informal or unstructured activity compared to time spent in school, so the opportunities of informal science activities in a child's total learning must not be missed. National Science Foundation, *Investing in America's Future: Strategic Plan FY2006-2011* (Arlington, VA: National Science Foundation, 2006).

[51] Also recommended in National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 1995* (Arlington, VA: National Science Foundation, 1983); The National Science Board, *America's Pressing Challenge - Building a Stronger Foundation: A Companion to Science and Engineering Indicators*, NSB-06-02 (Washington DC: Government Printing Office, 2006); and National Science Board, *Preparing Our Children: Math and Science Education in the National Interest* (Arlington, VA: National Science Foundation, 1999).

[52] National Governors Association and Council on Competitiveness, *Innovation America: A Partnership*, (Washington, DC: National Governors Association, February 24, 2007). p.7

[53] U.S. Commission on National Security/21st Century, *Road Map for National Security: Imperative for Change*, Phase III Report, p. 39 (February 15, 2001).

[54] Council of Great City Schools, *The Urban Teacher Challenge: Teacher Demand in the Great City Schools* (Washington, DC: Council of Great City Schools. 2000). Page 9-11.

[55] Also recommended in National Commission on Excellence in Education, *A Nation at Risk: The Imperative for Educational Reform* (Washington, DC: U.S. Department of Education, 1983); National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: U.S. Department of Education, 2000); and Building Engineering and Science Talent, *A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics* (Washington, DC: BEST, 2004).

[56] Also found in National Academy of Engineering, and Institute of Medicine of the National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, DC: National Academy of Sciences, 2005).

[57] Also recommended in National Commission on Excellence in Education, *A Nation at Risk: The Imperative for Educational Reform* (Washington, DC: U.S. Department of Education, 1983); National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: U.S. Department of Education, 2000); The National Science Board, *America's Pressing Challenge - Building a Stronger Foundation: A Companion to Science and Engineering Indicators*, NSB-06-02 (Washington DC: Government Printing Office, 2006); Building Engineering and Science Talent, *A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics* (Washington, DC: BEST, 2004) and National Governors Association and Council on Competitiveness, *Innovation America: A Partnership* (Washington, DC: National Governors Association, February 24, 2007). Page 6.

[58] Also recommended in National Commission on Excellence in Education, *A Nation at Risk: The Imperative for Educational Reform* (Washington, DC: U.S. Department of Education, 1983); National Science Board, *America's Pressing Challenge - Building a Stronger Foundation: A Companion to Science and Engineering Indicators*, NSB.-06-02 (Washington DC: Government Printing Office, 2006); and National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: U.S. Department of Education, 2000).

[59] The Robert Noyce Scholarship Program seeks to increase the number of teachers with a strong content knowledge in mathematics. This National Science Foundation program provides scholarship funds for talented undergraduate mathematics majors to become teachers in high need school districts. Likewise, stipends are available for professionals (who already have a bachelor's degree) seeking to become mathematics teachers committed to teaching in a high needs school. Scholarship and stipend recipients agree to teach two years in a high need school district for every year of scholarship funds received.

[60] This idea is reflected in a current piece of legislation, H.R. 362, the "10,000 Teachers, 10 Million Minds Science and Math Scholarship Act." Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/C?c110:./temp/~c110XaKNA8* (accessed March 15, 2007).

[61] National Education Association: "The average starting salary for a mathematics teacher is $12,769, based on 1981-82 figures. This compares with $22,368 for an engineer and $16,980 for accounting graduates."; "In 1997, teachers earned an average of $35,048 -- 71% of the average earnings of a worker with a baccalaureate degree. Nationally, the

average starting salary for teachers in 1997 was $25,735. Persons earning baccalaureate degrees in mathematics and science can make twice that salary in private industry." *Before It's Too Late,* National Commission on Mathematics and Science Teaching for the 21st Century U.S. Department of Education, 2000; and "Four out of ten mathematics and science teachers leave the profession because of job dissatisfaction; about 57% of these site salaries as the deciding factor. By contrast, 29% leave because of student discipline problems, and 21% leave because of poor student motivation." National Commission on Mathematics and Science Teaching for the 21st Century 10 March 2000.

[62] The National Science Board, *America's Pressing Challenge - Building a Stronger Foundation: A Companion to Science and Engineering Indicators*, NSB-06-02 (Washington DC: Government Printing Office, 2006).

[63] Also recommended in National Commission on Excellence in Education, *A Nation at Risk: The Imperative for Educational Reform* (Washington, DC: U.S. Department of Education, 1983); The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students So That Their Achievement is the Best in the World by 199*5 (Arlington, VA: National Science Foundation, 1983); National Science Board, "America's Pressing Challenge – Building a Stronger Foundation," *Companion to Science and Engineering Indicators 2006* (Arlington, VA: National Science Foundation, 2006); and National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: U.S. Department of Education, 2000).

[64] Also recommended in Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education* (Washington, DC: Business-Higher Education Forum, January 2005); Hart-Rudman Commission, *Road Map for National Security: Imperative for Change (Phase III)* (Washington, DC: 2001); The Research and Policy Committee of the Committee for Economic Development, *Learning for the Future: Changing the Culture of Math and Science Education to Ensure a Competitive Workforce* (Washington, DC: 2003); and Executive Office of the President/President's Council on Advisors on Science and Technology, *Sustaining the Nation's Innovation Ecosystem: Maintaining the Strength of Our Science and Engineering Capabilities* (Washington, DC: 2004).

[65] Also recommended in National Science Board, "America's Pressing Challenge – Building a Stronger Foundation," *Companion to Science and Engineering Indicators 2006* (Arlington, VA: National Science Foundation, 2006).

[66] Also recommended in American Association for the Advancement of Science, *A System of Solutions: Every School, Every Student* (Washington, DC: American Association for the Advancement of Science, 2005).

[67] This idea is reflected in a piece of legislation from the 109th Congress, S. 3710, "Teacher Center Act of 2006." This bill would provide grants to local education agencies for the establishment, operation and support of new and existing teacher centers in order to provide high-quality professional development and training. Library of Congress, "Thomas; Legislation in Current Congress," *http://thomas.loc.gov/cgi-bin/query/C?c109:./temp/~c109DCFOvi* (accessed 15 March 2007).

[68] Also recommended in National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: U.S. Department of Education, 2000).

[69] Also recommended in National Science Board, "America's Pressing Challenge – Building a Stronger Foundation," *Companion to Science and Engineering Indicators 2006* (Arlington, VA: National Science Foundation, 2006)

[70] Also recommended in National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late: A Report to the Nation* (Washington, DC: U.S. Department of Education, 2000).

[71] *Math and Science Education and United States Competitiveness: Does the Public Care?* "Less than one-third of the public (31 percent) believe that math and science classes offered to students not majoring in those fields are "very relevant" to life after graduation. In addition, only a slight majority of the public (54 percent) believe that all students should have to take more math and science courses." *http://www.acenet.edu/AM/Template.cfm?Section=Search&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=19215* For the Executive Summary of Survey (graphs, methodology) go to: *http://www.solutionsforourfuture.org/site/DocServer/Global_Competitiveness_Executive_Summary.pdf?docID=641* and for the Summary of Survey results: *http://www.cte.mnscu.edu/researchcorner/Future%20Work/MATH%20AND%20SCIENCE%20EDUCATION%20AND%20UNITED%20STATES%20COMPETITIVENESS.pdf*

Glossary

10-14 Pathways	Boundary-spanning curricular or institutional structures that enhance students' transition and access to colleges from secondary education.
Accreditation	Recognition by an agency or an association that an institution, program of study, individual, or service meets its criteria for accreditation
Articulation Agreement	Policy that allows a student to apply credits earned in specific programs at one institution toward advanced standing, equal transfer, or direct entry into specific programs at another institution
Assessment	Mechanisms to measure the learning and performance of students. Types of assessment include achievement tests, performance tasks, and developmental screening tests. Under No Child Left Behind, tests are aligned with academic standards
Benchmarks	A description of the level of student knowledge expected at specific grades, ages, or developmental levels.
Certification	Issuance of a formal document that certifies or declares that an educator possesses a set of skills, knowledge, and abilities, usually granted after completion of education, training, or experience in the related areas
Curriculum	The subjects and courses required to fulfill an educational program
Horizontal Coordination	Coherence among and within the fifty states to negotiate and integrate education policies into an overall strategy
Informal Science Education (ISE)	The learning of science experienced outside of the classroom
Informal Science Education (ISE) Institutions	Venues where the informal learning of science occurs including museums, national parks, and science fairs
Infrastructure	Basic framework, foundation, and resources of a system, organization, or activity that supports STEM education
Inquiry experiences	Process in which students investigate, work-through, and solve problems
In-service education	Continuing education for teachers following completion of pre-service training and employment. Also referred to as staff or professional development
Institutions of Higher Education	Accredited community colleges, four-year colleges, and universities
Instructional leadership	Administrators and educators who shift the emphasis of school activity more directly onto instructional improvements that lead to enhanced student learning and performance

Local Education Agencies	A public board of education or other authority within a state that maintains administrative control of public schools in a city, county, township, school district, or other political subdivision of a state
National Board Certification	A national teacher certification created in 1987 after the release of the Carnegie Forum on Education and the Economy's Task Force on Teaching as a Profession's, *A Nation Prepared: Teachers for the 21st Century.* These certifications are offered by the National Board for Professional Teaching Standards (NBPTS) and offer teachers the chance to voluntarily become nationally certified by demonstrating and maintaining high and rigorous standards in the Five Core Propositions developed by the NBPTS.
P-20 Council(s)	Body of education stakeholders including state and local policy makers, teachers, administrators, and parents designed to improve education and to address issues in its educational system
Pedagogy	The art and method of teaching
Pre-service preparation	Professional development and training of teachers prior to employment, usually while studying in institutions of higher education
Professional Development	Skills required to help teachers and administrators build knowledge and skills through continuing education programs such as conferences, classes and workshops
Research-based models tools, and strategies	Models, tools, and strategies based on empirical evidence that educators and administrators may use to teach more effectively
Standards	Standards denote points of reference against which individuals are compared or evaluated. Standards usually take two forms in curriculum: content standards that describe expected student knowledge in various subject areas and performance standards that specify expected learning levels and assess the degree to which content standards have been met
State Education Agencies	Agencies primarily responsible for the state supervision of public elementary and secondary schools
STEM	Science, Technology, Engineering and Mathematics
Vertical Alignment	Alignment of student learning between grade-levels (pre-K through graduate education)

Meeting Participants

The Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics would like to thank the following experts who addressed the Commission at one or more of our Meetings.

Mr. Norman Augustine
Retired Chairman and CEO, Lockheed Martin Corporation, and Chair, Committee on Prospering in the Global Economy of the 21st Century

Dr. Arden L. Bement, Jr.
Director, National Science Foundation

Mr. Arne Duncan
Chief Executive Officer, Chicago Public Schools

Dr. William C. Harris
President and CEO, Science Foundation Arizona

Mr. Bill Kurtis
President, Kurtis Productions, Inc.

Mr. Michael Lach
Director of Mathematics and Science, Chicago Public Schools

The Honorable Daniel Lipinski
United States House of Representatives

Dr. Cora Marrett
Incoming Assistant Director, Directorate for Education and Human Resources, National Science Foundation

Dr. Stephanie Pace Marshall
President, Illinois Mathematics and Science Academy

Mr. David R. Mosena
President and Chief Executive Officer, Museum for Science and Industry, Chicago

The Honorable Janet Napolitano
Governor of Arizona

Mr. Robert J. Shea
Counselor to the Deputy Director for Management, Office of Management and Budget

Dr. Donald E. Thompson
Acting Assistant Director, Directorate for Education and Human Resources, National Science Foundation

Dr. Iris Weiss
President, Horizon Research

Working Group Members

The Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics would like to thank the following working group members who donated their time and expertise to assist the Commission in identifying STEM education related issues and potential action items.

Dr. Linda Atkinson
Associate Director, K20 Center, University of Oklahoma

Mr. Steve Cousins
Superintendent, Reeths-Puffer School District, Michigan

Dr. John Falk
Professor, Oregon State University, and President, Institute for Learning Innovation

Dr. Suzanne Mitchell
Teacher Quality Enhancement Project Director, Arkansas Department of Higher Education

Ms. Jeanne Narum
Director, Project Kaleidoscope

Dr. Mary John O'Hair
Vice-Provost for School and Community Partnerships, University of Oklahoma

Ms. Gwen Pollock
Director of Professional Development, National Science Teachers Association, and Principal Educational Consultant, Illinois State Board of Education

Dr. William Schmidt
Professor, Michigan State University, and U.S. Research Coordinator for the Third International Mathematics and Science Study (TIMSS)

Dr. Robert Semper
Executive Associate Director, The Exploratorium

Dr. Jon Strauss
Member, National Science Board, and President Emeritus, Harvey Mudd College

Dr. Jerry Valadez
K-12 Science Coordinator, Fresno Unified School District

Dr. Iris Weiss
President, Horizon Research

Dr. Gerald Wheeler
Executive Director, National Science Teachers Association

Mr. James Woodland
Director, Science Education, Nebraska Department of Education

Appendix G

Public Comments on Draft National Action Plan

In August 2007 the Board solicited and received public comments on a draft of the national action plan. The final action plan incorporates the public's comments as appropriate. Comments, both critical and supportive, were received from the states, organizations, and individuals listed below. Titles and affiliations are listed as provided by the commenter.

States and Organizations

American Association of Physics Teachers – Toufic M. Hakim, Ph.D., Executive Officer

American Geological Institute – P. Patrick Leahy, Ph.D., Executive Director, and Gail M. Ashley, Ph.D., President

American Institute of Biological Sciences – Douglas J. Futuyma, Ph.D., President

American Institute of Physics – H. Frederick Dylla, Ph.D., Executive Director and CEO

American Meteorological Society – Keith L. Seitter, Ph.D., C.C.M., Executive Director

American Society of Mechanical Engineers Center for Public Awareness – Vince Wilczynski, Ph.D., Vice President

Association for Computing Machinery – Robert Schnabel, Ph.D., Chair, Education Policy Committee

Association of Science-Technology Centers – Bonnie VanDorn, Executive Director

Botanical Society of America – William M. Dahl, Executive Director

Commonwealth of Virginia – The Honorable Thomas R. Morris, Secretary of Education

Council of Graduate Schools – Debra W. Stewart, President

Greater Philadelphia Regional Compact for Science, Technology, Engineering and Mathematics (STEM) Education – Steering Group of the Member Organizations: Delaware Valley Industrial Resource Center, Math Science Partnership of Greater Philadelphia, Select Greater Philadelphia, Philadelphia Education Fund, WHYY

International Technology Education Association – Kendall N. Starkweather, Ph.D., Executive Director and CEO

National Center for Technological Literacy (NCTL), Museum of Science, Boston – Dr. Ioannis Miaoulis, Center Director and President of the Museum of Science; Dr. Yvonne Spicer, V.P. for Advocacy & Educational Partnerships; Dr. Cary Sneider, V.P. for Educator Programs; Dr. Christine Cunningham, V.P. for Research; Mr. Richard Blumenthal, V.P. for Publishing; Ms. Patti Curtis, Managing Director, Washington Office of the NCTL

National Council of Teachers of Mathematics – Jim Rubillo, Executive Director

National High Magnetic Field Laboratory – Gregory S. Boebinger, Director

National School Boards Association – Anne L. Bryant, Executive Director

National Science Digital Library – Kaye Howe, Director

National Science Teachers Association – Dr. Gerald Wheeler, Executive Director

Sigma Xi – James W. Porter, President

Society of Manufacturing Engineers Education Foundation – Glen H. Pearson, President, and Bart Aslin, Director

State of Hawai'i – The Honorable Linda Lingle, Governor of Hawai'i

State of Maryland – Dr. Nancy S. Grasmick, State Superintendent of Schools

State of West Virginia –The Honorable Joe Manchin III, Governor of West Virginia

State of Wisconsin – The Honorable Jim Doyle, Governor of Wisconsin

Tennessee Department of Education – Linda Jordan, Science K-12 Coordinator

Individuals

William Abikoff, Professor of Mathematics, University of Connecticut

Diane W. Adams, M.A., Star Tannery, Virginia

Dr. Ayodele Aina, Chair, Mathematics and Computer Sciences, Cheyney University of Pennsylvania

Robert Akeson

Martin Apple, Ph.D., President, Council of Scientific Society Presidents

Diola Bagayoko, Ph.D., Southern University System Distinguished Professor of Physics, Adjunct Professor of Science and Mathematics Education, Director, LS-LAMP and the Timbuktu Academy

Darlyne Bailey, Ph.D., Dean & Assistant to the President, Campbell Leadership Chair in Education and Human Development, College of Education and Human Development, University of Minnesota

Art Bardige, President, Enablearning

Christopher F. Bauer, Professor and Chair, Department of Chemistry, University of New Hampshire

Robert J. Beichner, Ph.D., Co-Director, NCSU STEM Education Initiative, Alumni Distinguished Professor of Physics, North Carolina State University

Daniel B. Berch, Ph.D.

Anita Bernhardt, Science & Technology Specialist and Regional Representative, Maine Department of Education

Pierre Bierre, Founder and CEO, BuildExact Corp

Karen J.L. Burg, Ph.D., Hunter Endowed Chair and Professor of Bioengineering, Interim Vice Provost for Research & Innovation, Clemson University

Crista Carlile, Science Curriculum Coordinator, Des Moines Public Schools

Jay Cole, Education Policy Advisor to West Virginia Governor Joe Manchin III

Terry Daugherty, Batchelor Middle School, Bloomington, Indiana

M. Daniel DeCillis, Ph.D., Senior Research Associate and Director of Web Operations, California Council on Science and Technology

Diana Dummit, Co-PI, Institute for Chemistry Literacy through Computational Science, National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign

Thom Dunning, Director, National Center for Supercomputing Applications, and PI, Institute for Chemistry Literacy through Computational Science, National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign

Francis Eberle, Ph.D., Executive Director, Maine Mathematics and Science Alliance

Tami R. Ellison, how2SCIENCE

Patricia L. Eng, P.E., Derwood, Maryland

Gualterio Nunez Estrada, Sarasota, Florida

Noreen Ewick, Middle School Teacher, Holyoke, Massachusetts

Dr. Evelina Félicité-Maurice, NASA Heliophysics Projects Division, Education and Public Outreach Program Planning Manager

Dr. Teresa Franklin, Associate Professor, Instructional Technology Educational Studies Department, College of Education, Ohio University

Bill Gibbard, Science Coordinator, Allentown School District

Howard Gobstein, Vice President, Research and Science Policy, National Association of State Universities and Land Grant Colleges (NASULGC)

Al Gomez, Engineering Instructor, CTE Coordinator, Sun Prairie Area School District, Wisconsin

Daniel L. Goroff, Co-Director, Scientific and Engineering Workforce Project based at the National Bureau of Economic Research

Charles R. Granger, Ph.D., Professor of Biology and Education Curators' Distinguished Teaching Professor, Departments of Biology and Education, University of Missouri-St. Louis

Raymond R. Grosshans, Ph.D., Program Coordinator, Center for Advanced Energy Studies, Idaho National Laboratory

Jong-on Hahm, Ph.D., Research Professor, George Washington University

Carol Hakobian, Fifth Grade Teacher, Serrania Avenue School, Woodland Hills, California

Trisha Herminghaus, Anchorage, Alaska

Andrea Hickson, Middle School Teacher, Holyoke, Massachusetts

Pao-sheng Hsu

Dale Ingram, Education and Outreach Coordinator, LIGO Hanford Observatory, Richland, Washington

Eric Jakobsson, Director of Research to Learning, Institute for Chemistry Literacy through Computational Science, National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign

Larry Johnson

Cathy Kessel

Andrew C. Klein, Ph.D., P.E., Director, Educational Partnerships, Idaho National Laboratory

Professor Lawrence Klein, Massachusetts

William Knight, Physical Scientist, NOAA/NWS

Eve Lewis, Sing Science, LLC

Edward S. Lowry, Bedford, Massachusetts

Denise Mann

Mike Mansour, Retired Middle School Science Teacher, Lake Orion, Michigan

J.V. Martinez, Ph.D., Senior Advisor for Scientific Institutional Outreach, Department of Energy

Kari McCarron, Senior Legislative Assistant, Massachusetts Institute of Technology Washington Office

Della McCaughan, Mississippi

F. Joseph Merlino, Principal Investigator and Project Director, Math Science Partnership of Greater Philadelphia

Bernadette Monahan, M.A., Star Tannery, Virginia

John Mosto, Member, Massachusetts Department of Education Math/Science Advisory Council

Mary Obringer, Science Teacher

Deborah A. Pace, Ph.D., Professor and Coordinator of Administration, Department of Mathematics and Statistics, Stephen F. Austin State University

Robert Baird Paterson

Walter Paul, Ph.D., Belle Mead, New Jersey

Carl Pennypacker, University of California at Berkeley and Co-Leader, Hands-On Universe

Dr. Wes Perusek, Director, Ohio Space Grant Consortium (NASA) Invention Innovation Centers Project

Ralph Peterson, Science Teacher, North Gem High School, Bancroft, Idaho

Evelyn A. Puaa, Mathematics Educator, Mathematics Teacher Educator, Doctoral Student, Hawai'i

Johann Rafelski, Professor of Physics, University of Arizona

Samuel M. Rankin, III, Ph.D., Associate Executive Director, American Mathematical Society

Bob Raynolds, Ph.D., Research Associate, Denver Museum of Nature & Science

Catherine Reed, Director, Bachelor's Plus Early Pathway, California State University, East Bay

Elsie M. Colon Rodriguez, Director, Turabo Alliance for Better Schools, Exploring my Universe!, GEAR UP

Laurie F. Ruberg, Ph.D., Associate Director, Center for Educational Technologies, Wheeling Jesuit University

Mark Sanders, Professor & Program Leader, Technology Education, Affiliate Faculty Member, Engineering Education, Virginia Tech

Barb Sauer, Winneconne High School, Wisconsin

Patricia Seawell, Gene Connection:Chem Connection

Cecily Cannan Selby, Co-Chair, NSB 1983 Commission: "Educating Americans for the Twenty-First Century"

Diane Spect, South Carolina

Daniel L. Stabile, Ph.D., Bishop O'Connell High School, Arlington, Virginia

Deiadra D. Swartz, Concerned Writer/Professor/Lawyer & Mom, Parker, Colorado

Dr. Herbert D. Thier, Academic Administrator Emeritus, University of California, Berkeley; Co-Director, Education and Public Outreach, UC Berkeley BIOMARS Institute; and Founding Director, SEPUP

Claudia Toback, CMT Educational Consulting

Joe Tuggle, Graduate Student, BaBar Collaboration, Stanford Linear Accelerator Center

Todd Ullah, Ed.D., Director of Secondary Science Programs, Los Angeles Unified School District

Dr. Gordon E. Uno, Chair and David Ross Boyd Professor of Botany, Department of Botany and Microbiology, University of Oklahoma

Alice P. Wakefield, Early Childhood Teacher Educator, Old Dominion University

Darryl N. Williams, Ph.D., Executive Director, iPRAXIS, Inc.

Edee Wiziecki, Co-PI, Institute for Chemistry Literacy through Computational Science, National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign

David E. Wojick, Ph.D., Star Tannery, Virginia

Joanne Zosel, High School Mathematics and Science Teacher

Obtaining the Board Action Plan

The action plan is available electronically at: *http://www.nsf.gov/nsb/documents/2007/stem_action.pdf*

Paper copies of the action plan can be ordered by submitting a Web-based order form at: *http://www.nsf.gov/publications/orderpub.jsp* or contacting NSF Publications at 703-292-7827.

Other options for obtaining the documents: TTY: 800-281-8749; FIRS: 800-877-8339.

For special orders or additional information, contact the National Science Board Office: NSBOffice@nsf.gov or 703-292-7000.

National Science Foundation
Arlington, VA 22230

OFFICIAL BUSINESS

NSB-07-114