



REPORT TO THE PRESIDENT
ENGAGE TO EXCEL: PRODUCING ONE MILLION
ADDITIONAL COLLEGE GRADUATES WITH
DEGREES IN SCIENCE, TECHNOLOGY,
ENGINEERING, AND MATHEMATICS

Executive Office of the President
President's Council of Advisors
on Science and Technology

FEBRUARY 2012





About the President's Council of Advisors on Science and Technology

The President's Council of Advisors on Science and Technology (PCAST) is an advisory group of the nation's leading scientists and engineers, appointed by the President to augment the science and technology advice available to him from inside the White House and from cabinet departments and other Federal agencies. PCAST is consulted about and often makes policy recommendations concerning the full range of issues where understandings from the domains of science, technology, and innovation bear potentially on the policy choices before the President.

For more information about PCAST, see www.whitehouse.gov/ostp/pcast.



The President's Council of Advisors on Science and Technology

Co-Chairs

John P. Holdren

Assistant to the President for
Science and Technology
Director, Office of Science and Technology Policy

Eric Lander

President
Broad Institute of Harvard and MIT

Vice Chairs

William Press

Raymer Professor in Computer Science and
Integrative Biology
University of Texas at Austin

Maxine Savitz

Vice President
National Academy of Engineering

Members

Rosina Bierbaum

Professor of Natural Resources and
Environmental Policy
School of Natural Resources and Environment
and School of Public Health
University of Michigan

Shirley Ann Jackson

President
Rensselaer Polytechnic Institute

Christine Cassel

President and CEO
American Board of Internal Medicine

Richard C. Levin

President
Yale University

Christopher Chyba

Professor, Astrophysical Sciences and
International Affairs
Director, Program on Science and Global Security
Princeton University

Chad Mirkin

Rathmann Professor, Chemistry, Materials
Science and Engineering, Chemical and
Biological Engineering and Medicine
Director, International Institute for
Nanotechnology
Northwestern University

S. James Gates, Jr.

John S. Toll Professor of Physics
Director, Center for String and Particle Theory
University of Maryland, College Park

Mario Molina

Professor, Chemistry and Biochemistry
University of California, San Diego
Professor, Center for Atmospheric Sciences at the
Scripps Institution of Oceanography
Director, Mario Molina Center for Energy and
Environment, Mexico City

Mark Gorenberg

Managing Director
Hummer Winblad Venture Partners

Ernest J. Moniz

Cecil and Ida Green Professor of Physics and
Engineering Systems
Director, MIT's Energy Initiative
Massachusetts Institute of Technology

Craig Mundie

Chief Research and Strategy Officer
Microsoft Corporation

Ed Penhoet

Director, Alta Partners
Professor Emeritus, Biochemistry and Public
Health
University of California, Berkeley

Barbara Schaal

Mary-Dell Chilton Distinguished Professor of
Biology
Washington University, St. Louis
Vice President, National Academy of Sciences

Eric Schmidt

Executive Chairman
Google, Inc.

Daniel Schrag

Sturgis Hooper Professor of Geology
Professor, Environmental Science and
Engineering
Director, Harvard University Center for the
Environment
Harvard University

David E. Shaw

Chief Scientist, D.E. Shaw Research
Senior Research Fellow, Center for
Computational Biology and Bioinformatics
Columbia University

Ahmed Zewail

Linus Pauling Professor of Chemistry and Physics
Director, Physical Biology Center
California Institute of Technology

Staff**Deborah Stine**

Executive Director

Danielle Evers

AAAS Science and Technology Policy Fellow

Amber Hartman Scholz

Assistant Executive Director



EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

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

Dear Mr. President,

We are pleased to present you with this report, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*, prepared for you by the President's Council of Advisors on Science and Technology (PCAST). This report provides a strategy for improving STEM education during the first two years of college that we believe is responsive to both the challenges and the opportunities that this crucial stage in the STEM education pathway presents.

In preparing this report, PCAST assembled a Working Group of experts in postsecondary STEM teaching, learning-science research, curriculum development, higher-education administration, faculty training, educational technology, and successful interaction between industry and higher education. The report was strengthened by input from additional experts in postsecondary STEM education, STEM practitioners, professional societies, private companies, educators, and Federal education officials.

PCAST found that economic forecasts point to a need for producing, over the next decade, approximately 1 million more college graduates in STEM fields than expected under current assumptions. Fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree. Merely increasing the retention of STEM majors from 40% to 50% would generate three-quarters of the targeted 1 million additional STEM degrees over the next decade.

PCAST identified five overarching recommendations that it believes can achieve this goal: (1) catalyze widespread adoption of empirically validated teaching practices; (2) advocate and provide support for replacing standard laboratory courses with discovery-based research courses; (3) launch a national experiment in postsecondary mathematics education to address the mathematics-preparation gap; (4) encourage partnerships among stakeholders to diversify pathways to STEM careers; and (5) create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.

Implementing these recommendations will help you achieve one of the key STEM goals you stated in your address to the National Academy of Sciences in April 2009: "American students will move from the middle to the top of the pack in science and math over the next decade. For we know that the nation that out-educates us today—will out-compete us tomorrow." The members of PCAST are grateful for the opportunity to provide our input on an issue of such critical importance to the Nation's future.

Sincerely,

John P. Holdren
PCAST Co-Chair

Eric Lander
PCAST Co-Chair



Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics

Executive Report

Economic projections point to a need for approximately 1 million more STEM professionals than the U.S. will produce at the current rate over the next decade if the country is to retain its historical preeminence in science and technology. To meet this goal, the United States will need to increase the number of students who receive undergraduate STEM degrees by about 34% annually over current rates.

Currently the United States graduates about 300,000 bachelor and associate degrees in STEM fields annually. Fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree. Increasing the retention of STEM majors from 40% to 50% would, alone, generate three-quarters of the targeted 1 million additional STEM degrees over the next decade. Many of those who abandon STEM majors perform well in their introductory courses and would make valuable additions to the STEM workforce. Retaining more students in STEM majors is the lowest-cost, fastest policy option to providing the STEM professionals that the nation needs for economic and societal well-being, and will not require expanding the number or size of introductory courses, which are constrained by space and resources at many colleges and universities.

The reasons students give for abandoning STEM majors point to the retention strategies that are needed. For example, high-performing students frequently cite uninspiring introductory courses as a factor in their choice to switch majors. And low-performing students with a high interest and aptitude in STEM careers often have difficulty with the math required in introductory STEM courses with little help provided by their universities. Moreover, many students, and particularly members of groups underrepresented in STEM fields, cite an unwelcoming atmosphere from faculty in STEM courses as a reason for their departure.

Better teaching methods are needed by university faculty to make courses more inspiring, provide more help to students facing mathematical challenges, and to create an atmosphere of a community of STEM learners. Traditional teaching methods have trained many STEM professionals, including most of the current STEM workforce. But a large and growing body of research indicates that STEM education can be substantially improved through a diversification of teaching methods. These data show that evidence-based teaching methods are more effective in reaching all students—especially the “underrepresented majority”—the women and members of minority groups who now constitute approximately 70% of college students while being underrepresented among students who receive undergraduate STEM degrees (approximately 45%). This underrepresented majority is a large potential source of STEM professionals.

The Need for an Improved STEM Student Recruitment and Retention Strategy for the First Two Years of Postsecondary Education

The first two years of college are the most critical to the retention and recruitment of STEM majors. These two years are also a shared feature of all types of 2- and 4-year colleges and universities—community colleges, comprehensive universities, liberal arts colleges, research universities, and minority-serving institutions. In addition, STEM courses during the first two years of college have an enormous effect on the knowledge, skills, and attitudes of future K-12 teachers. For these reasons, this report focuses on actions that will influence the quality of STEM education in the first two years of college.

Based on extensive research about students' choices, learning processes, and preparation, three imperatives underpin this report:

- Improve the first two years of STEM education in college.
- Provide all students with the tools to excel.
- Diversify pathways to STEM degrees.

Our recommendations, described below, detail how to convert these imperatives into action.

The title of this report, "Engage to Excel," applies to students, faculty, and leaders in academia, industry, and government. Students must be engaged to excel in STEM fields. To excel as teachers, faculty must engage in methods of teaching grounded in research about why students excel and persist in college. Moreover, success depends on the engagement by great leadership. Leaders, including the President of the United States; college, university and business leadership; and others, must encourage and support the creation of well-aligned incentives for transforming and sustaining STEM learning. They also must encourage and support the establishment of broad-based reliable metrics to measure outcomes in an ongoing cycle of improvement.

Transforming STEM education in U.S. colleges and universities is a daunting challenge. The key barriers involve faculty awareness and performance, reward and incentive systems, and traditions in higher education. The recommendations in this report address the most significant barriers and use both tangible resources and persuasion to inspire and catalyze change. Attacking the issue from numerous angles and with various tools is aimed at reaching a point at which the movement will take on a momentum of its own and produce sweeping change that is sustainable without further Federal intervention.

Recommendations

The President's Council of Advisors on Science and Technology (PCAST) proposes five overarching recommendations to transform undergraduate STEM education during the transition from high school to college and during the first two years of undergraduate STEM education:

- 1. Catalyze widespread adoption of empirically validated teaching practices.**
- 2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.**

- 3. Launch a national experiment in postsecondary mathematics education to address the math preparation gap.**
- 4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.**
- 5. Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.**

Each of these recommendations will be explained in more detail below.

Recommendation 1.

Catalyze widespread adoption of empirically validated teaching practices.

Learning theory, empirical evidence about how people learn, and assessment of outcomes in STEM classrooms all point to a need to improve teaching methods to enhance learning and student persistence. Classroom approaches that engage students in “active learning” improve retention of information and critical thinking skills, compared with a sole reliance on lecturing, and increase persistence of students in STEM majors. STEM faculty need to adopt teaching methods supported by evidence derived from experimental learning research as well as from learning assessment in STEM courses. Evidence-based teaching methods have proven effective with a wide range of class sizes and increase learning outcomes even as enhancements of traditional lectures.

A significant barrier to broad implementation of evidence-based teaching approaches is that most faculty lack experience using these methods and are unfamiliar with the vast body of research indicating their impact on learning. The Federal Government could have a major impact by providing substantial support for programs that provide training for current and future faculty in evidence-based teaching methods and provide materials to support the application of such methods. Established programs run by the National Academies and the American Association of Physics Teachers/American Physical Society/American Astronomical Society have trained many faculty, and evaluations of these programs have demonstrated that they change the participants’ teaching methods and have positive effects on student achievement and engagement. These programs provide successful models for replication and expansion.

Although evidence-based teaching methods do not necessarily require more resources than traditional lectures, the transition requires time and effort that can be costly for colleges and universities. Given the Federal Government’s interest in maintaining a strong STEM workforce, Federal support, in partnership with private and academic institutional investment, will be needed to initiate these changes, after which they can be sustained over the long term without external assistance.

Ongoing change toward the goal described here requires the ability to measure progress. Metrics for excellence in undergraduate STEM education would provide tools for institutions, departments, funding agencies, external evaluators, accreditation agencies, students choosing where to study STEM subjects, and those designing innovative programs. Flexible criteria are needed to account for the wide range of institutions and disciplines that will use these tools to direct change.

Actions to achieve Recommendation 1.

1-1 Establish discipline-focused programs funded by Federal research agencies, academic institutions, disciplinary societies, and foundations to train current and future faculty in evidence-based teaching practices.

Successful programs should be expanded to reach 10% to 20% of the nation's 230,000 STEM faculty over the next five years. The expansion should make training available to faculty from diverse backgrounds to provide role models for all students and from all disciplines and types of institutions. Based on data from existing teaching training programs, it is reasonable to expect trained faculty to influence the teaching of 10 colleagues, making it possible to reach a substantial proportion of the STEM faculty through programs targeted at a subset of faculty. Moreover, approximately 10% of the STEM faculty teach the introductory courses to first- and second-year college students. Therefore, the goal of reaching 10% to 20% of the STEM faculty directly could result in training most of those who teach in the first two years of college.

A total of \$10-15 million per year over 5 years will be required for the training of 23,000 to 46,000 STEM faculty. Funds for this training should be derived from a combination of Federal programs academic institutions, disciplinary societies, and foundations. To train future faculty, Federal research agencies should require all graduate students and postdoctoral fellows supported by federal training grants to receive instruction in modern teaching methods. A combination of training grant and institutional funds should be dedicated to this training effort.

1-2 Create a "STEM Institutional Transformation Awards" competitive grants program at NSF.

A competitive grants program should be designed to provide incentives for and facilitate teaching innovations at 2- and 4-year institutions. Grants should support model programs and electronic dissemination of successful practices. The grants program should have funding of \$20 million per year, to support approximately 100 multi-year projects with average total support of \$1 million over a 5-year period. Funding could come from enactment of NSF's proposed Widening Implementation and Demonstration of Evidence-Based Reforms (WIDER) program at the Presidents' Fiscal Year 2012 requested level of \$20 million annually.

1-3 Request that the National Academies develop metrics to evaluate STEM education.

To evaluate progress toward the goals presented in this report, campuses, funders, students, and accreditation agencies need a meaningful set of criteria by which to measure excellence in STEM education. NSF and the U.S. Department of Education should request The National Academies to lead an effort to develop metrics supported by empirical evidence that encourage and assess faculty practices and student learning.

Recommendation 2.

Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.

Traditional introductory laboratory courses generally do not capture the creativity of STEM disciplines. They often involve repeating classical experiments to reproduce known results, rather than engaging

students in experiments with the possibility of true discovery. Students may infer from such courses that STEM fields involve repeating what is known to have worked in the past rather than exploring the unknown. Engineering curricula in the first two years have long made use of design courses that engage student creativity. Recently, research courses in STEM subjects have been implemented at diverse institutions, including universities with large introductory course enrollments. These courses make individual ownership of projects and discovery feasible in a classroom setting, engaging students in authentic STEM experiences and enhancing learning and, therefore, they provide models for what should be more widely implemented.

Actions to achieve Recommendation 2.

2-1 Expand the use of scientific research and engineering design courses in the first two years through an NSF program.

The National Science Foundation should provide initial funding to replicate and scale-up model research or design courses, possibly through the existing Transforming Undergraduate Education in STEM (TUES) program or the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP). On the order of 30% of the existing programs across STEM disciplines could be focused on funding implementation of research courses at postsecondary academic institutions at an annual cost of approximately \$12.5 million dollars (based on Fiscal Year 2010 funding levels). Based on the range of funding for Type 3 TUES grants and Type 1 STEP grants, about 10 proposals per year at an average level of \$1.2 million could be awarded, in order to impact 100 campuses over the next 10 years.

Colleges and universities should seek to match NSF funding with private and philanthropic sources. Research courses should be an encouraged element of STEM Institutional Transformation Awards. Because research courses will replace expensive introductory laboratory courses, they should not require ongoing external support once the transition is accomplished.

2-2 Expand opportunities for student research and design in faculty research laboratories by reducing restrictions on Federal research funds and redefining a Department of Education program.

Independent research on faculty projects is a direct way for students to experience real discovery and innovation and to be inspired by STEM subjects. All relevant Federal agencies should examine their programs which support undergraduate research and where there exists prohibitions, either in policy or practice, which would interfere with the recommendations of this report to support early engagement of students in research, these should be changed. Federal agencies should encourage projects that establish collaborations between research universities and community colleges or other institutions that do not have research programs. Cross-institutional research opportunities could be funded through redefinition of the Department of Education's \$1 billion Carl D. Perkins Career and Technical Education program and by sharpening the focus of Federal investments in minority institutions.

Recommendation 3.

Launch a national experiment in postsecondary mathematics education to address the mathematics-preparation gap.

College-level skills in mathematics and, increasingly, computation are a gateway to other STEM fields. Today many students entering college lack these skills and need to learn them if they are to pursue STEM majors. In addition, employers in the private sector, government, and military frequently cite that they cannot find enough employees with needed levels of mathematics skills. This lack of preparation imposes a large burden on higher education and employers. Higher education alone spends at least \$2 billion per year on developmental education to compensate for deficiencies. Also, introductory mathematics courses often leave students with the impression that all STEM fields are dull and unimaginative, which has particularly harmful effects for students who later become K-12 teachers. Reducing or eliminating the mathematics-preparation gap is one of the most urgent challenges—and promising opportunities—in preparing the workforce of the 21st century.

Closing this gap will require coordinated action on many fronts starting in the earliest grades. PCAST's earlier report on K-12 STEM education, *Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future*, contains several recommendations that involve colleges and universities in this effort. In particular, it calls for the Federal Government to establish the objective of recruiting, preparing, and providing induction support for at least 100,000 new STEM middle and high school teachers who have majors in STEM fields and strong content-specific pedagogical preparation. This Administration has embraced this goal, and production of 1 million additional STEM graduates over the next decade could contribute substantially to meeting it.

The Federal Government has a critical role in supporting the development of a knowledge base to close the mathematics-preparation gap. For example, research into the best ways to teach math to older students so they can pursue STEM subjects in the first two years of college is badly needed. Some developmental mathematics courses have demonstrated effectiveness in increasing math proficiency among those not ready for college-level math and even in encouraging students intending to major in STEM subjects to persist to graduation and a STEM degree. Mathematics education research should explore the attributes of these successful classes and ways to disseminate best practices.

In the *Prepare and Inspire* report, PCAST also called for the creation of a mission-driven, Advanced Research Projects Agency for Education (ARPA-Ed) that would propel and support (1) the development of innovative technologies and technology platforms for learning, teaching, and assessment across all subjects and ages, and (2) the development of effective, integrated, whole-course materials for STEM education. Many of these advances would benefit not only K-12 education but also the developmental courses that many students need to pursue STEM fields during the first two years of college.

Actions to achieve Recommendation 3.

3-1 Support a national experiment in mathematics undergraduate education at NSF, the Department of Labor, and the Department of Education.

The National Science Foundation and the Departments of Labor and Education should support a multi-campus 5-year initiative aimed at developing new approaches to remove or reduce the mathematics bottleneck that is currently keeping many students from pursuing STEM majors.

This national experiment should fund a variety of approaches, including (1) summer and other bridge programs for high school students entering college; (2) remedial courses for students in college, including approaches that rely on computer technology; (3) college mathematics teaching and curricula developed and taught by faculty from mathematics-intensive disciplines other than mathematics, including physics, engineering, and computer science; and (4) a new pipeline for producing K-12 mathematics teachers from undergraduate and graduate programs in mathematics-intensive fields other than mathematics. Diverse institutions should be included in the experiment to assess the impact of the intervention on various types of students and schools. Outcome evaluations should be designed as a collective effort by the participating campuses and funding agencies.

Approximately 200 experiments at an average level of \$500,000 should be funded at institutions across the country, at an annual cost of \$20 million per year for 5 years. As mathematics preparation issues vary across the postsecondary spectrum, a variety of sources will be needed to fund experiments at diverse institution types. Funds for these experiments could be derived from a combination of the Department of Education's proposed First in the World Initiative, possibly the Department of Labor's Career Pathways Innovation Fund or Trade Adjustment Assistance Community College and Career Training initiative, and a strategic focus on mathematics of NSF's Transforming Undergraduate Education in STEM (TUES) program or Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) for the next 5 years.

Recommendation 4.

Encourage partnerships among stakeholders to diversify pathways to STEM careers.

To take advantage of the breadth of available talent, non-traditional students should receive special attention. Adult and working students and those from backgrounds atypical of traditional STEM students may need alternative pathways to be successful in STEM disciplines. The concept of a "pipeline" to STEM competency and accomplishment needs to be superseded by the image of multiple pathways to these goals. All colleges and universities, including 2- and 4-year institutions, need better connections among themselves and with other institutions to provide more entry points and pathways to STEM degrees.

Actions to achieve Recommendation 4.

Establishing and supporting pathways will require a coordinated effort among diverse institutions. The Federal Government can lead this effort and encourage the necessary partnerships through strategic planning, reallocation of funds, and leadership.

4-1 Sponsor at the Department of Education summer STEM learning programs for high school students.

The Department of Education should roll-out the summer learning programs authorized in the 2007 America Competes Act (in an amendment introduced by then-Senator Obama) to provide mathematics instruction and hands-on STEM experiences for rising high school juniors and seniors. The programs should be funded by partnerships among the Federal Government, states, local entities, and private industry. Based on the size of National Science Foundation's

former Young Scholars Program for summer institutes, we recommend an investment of \$10 million to fund approximately 100 projects reaching on the order of 5000 students, annually, with significant cost sharing with academic institutions and private investors.

4-2 Encourage pathways from 2- to 4-year institutions through an NSF program and expanded definition of a Department of Labor Program.

The mission of the Department of Labor's Trade Adjustment Assistance Community College and Career Training initiative should be expanded beyond development of important partnerships between community and technical colleges and employers in the private sector to encourage scientific research and engineering design exchanges across two- and four-year institutions. Alternatively, these activities could be funded through a strategic focus of the Department of Labor's Career Pathways Innovation Fund on research partnerships. NSF's Advancing Technical Education program could also be focused on cross institutional collaborations. The bridges described here should provide authentic STEM experiences for community college students on the four-year campus and allow students to develop relations with faculty and the college or university community to ease the potential transition from a 2- to 4-year institution or to provide advanced experiences for students who do not pursue a four year degree.

4-3 Establish public-private partnerships to support successful STEM programs.

To enhance students' STEM readiness, the Federal Government should engage private industry and foundations to support successful programs that create bridges between high schools and colleges and between 2- and 4-year institutions and ensure that programs incorporate learning standards and content consistent with industry-recognized skills.

4-4 Improve data provided by the Department of Education and the Bureau of Labor Statistics to STEM students, parents, and the greater community on STEM disciplines and the labor market.

To promote pathways to STEM careers for non-traditional students, the Federal Government should provide current and comprehensive data on STEM jobs. Today, public and private employers of STEM professionals lack data about the skills, choices, and availability of STEM workers. To produce needed information, the 1988 cohort and the *High School and Beyond* cohort should be resurveyed; the Department of Education should devote more resources to tracking students from high school into their careers; and the Bureau of Labor Statistics should redefine employment categories to include in "STEM" the breadth of jobs that require STEM skills, such as medical careers and advanced manufacturing professions.

Recommendation 5.

Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.

The leadership of higher education and STEM-enabled businesses needs to be inspired to generate sweeping changes in higher education to produce the workforce America needs. Toward this end, we recommend that the President, via Executive Order, form a Presidential Council on STEM Education to

EXECUTIVE REPORT

provide advice and leadership on postsecondary STEM education. The council should include members that represent the breadth of academic institutions, professional societies, businesses, and private foundations involved in the development and use of human capital in STEM fields. Based on the guidance provided in this report, the council should make recommendations that advance the quality of postsecondary STEM education through all mechanisms available to the President. The council could provide a forum for leaders in the public and private sectors to weigh in on the development and deployment of metrics to evaluate STEM departments (Recommendation 1) and to design collaborative coalitions to support initiatives in STEM education (Recommendation 4), including expanding internship programs in industry and connecting industrial research agendas with research courses (Recommendation 2). In addition, it could provide advice and review for the National Experiment in Math Undergraduate Education (Recommendation 3) and could conduct further study of the math education issue, if necessary.

OVERVIEW OF PCAST RECOMMENDATIONS TO ENGAGE AND EXCEL IN UNDERGRADUATE SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) EDUCATION

Recommendation 1: Catalyze widespread adoption of empirically validated teaching practices.

- 1-1** Establish discipline-focused programs funded by Federal research agencies, academic institutions, disciplinary societies, and foundations to train current and future faculty in evidence-based teaching practices.
- 1-2** Create the “STEM Institutional Transformation Awards” competitive grants program at NSF.
- 1-3** Request that the National Academies develop metrics to evaluate STEM education.

Recommendation 2: Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.

- 2-1** Expand the use of scientific research and engineering design courses in the first two years of postsecondary education through an NSF program.
- 2-2** Expand opportunities for student research and design in faculty research laboratories by reducing restrictions on Federal research funds and redefining a Department of Education program.

Recommendation 3: Launch a national experiment in postsecondary mathematics education to address the mathematics-preparation gap.

- 3-1** Support a national experiment in mathematics undergraduate education at NSF, the Department of Labor, and the Department of Education.

Recommendation 4: Encourage partnerships among stakeholders to diversify pathways to STEM careers.

- 4-1** Sponsor at the Department of Education summer STEM learning programs for high school students.
- 4-2** Expand the scope of a Department of Labor Program and focus an NSF program to encourage pathways from 2-to 4-year institutions.
- 4-3** Establish public-private partnerships to support successful STEM programs.
- 4-4** Improve data provided by the Department of Education and the Bureau of Labor Statistics to STEM students, parents, and the greater community on STEM disciplines and the labor market.

Recommendation 5: Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.

**ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES
WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS**

Engage to Excel: Summary of Recommendations, Actions, and Estimated Costs	
1. Catalyze widespread adoption of empirically validated teaching practices.	
Action	Agency and Estimated Cost
Establish discipline-focused programs funded by Federal agencies, academic institutions, professional societies, and foundations to train (1) current and (2) future faculty in evidence-based teaching practices.	<ol style="list-style-type: none"> 1. NSF and other agencies should partner with foundations and disciplinary societies to expand existing teacher training programs (\$10-\$15 M per year over five years to train 23,000 to 46,000 STEM faculty). 2. All agencies that provide training grants for graduate students and postdocs, through a combination of training grants and institutional funds.
(1) Create a “STEM Institutional Transformation Awards” competitive grants program at NSF.	1. NSF’s proposed Widening Implementation and Demonstration of Evidence-based Reforms (WIDER) program. \$20 M per year over five years to fund 100 multi-year projects.
(2) Develop an online presence to share data and best practices.	2. Education through proposed First in the World Initiative or ARPA-Ed.
Request that the National Academies develop metrics to evaluate STEM education.	NSF and Education to request this study, with cost to be determined.
2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.	
Action	Agency and Estimated Cost
Expand the use of scientific research and engineering design courses in the first two years through an NSF program.	NSF, with initial funding possibly through Transforming Undergraduate Education in Science (TUES) or Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) at \$12.5 M, annually (i.e. 10 Type 3 TUES or Type 1 STEP proposals per year at an average of \$1.2M).
Expand opportunities for student research in faculty laboratories by (1) reducing restrictions on Federal research funds, (2) giving special consideration to training grants that establish collaborations between research universities and other institutions, and (3) redefining a Department of Education program.	<ol style="list-style-type: none"> 1. All Federal agencies should make it possible to use undergraduate research program funds for first- and second-year students. 2. Federal agencies that fund programs for minority institutions could encourage cross-institution research partnerships. 3. Include research opportunities as technical education, such as that supported by the Department of Education’s Carl D. Perkins CTE program.
3. Launch a national experiment in postsecondary mathematics education to address the mathematics-preparation gap.	
Action	Agency and Estimated Cost
Support a national experiment in mathematics undergraduate education focused on: (1) summer programs; (2) remedial courses including use of technology; (3) discipline-based mathematics instruction, and (4) new pathways for K-12 mathematics teachers.	Fund 200 sites at an average of \$500,000 over five years, or \$20 M per year for five years, with funds from: NSF’s TUES or STEP programs, DOL’s Trade Adjustment Assistance Community College and Career Training (TAACCT) Grant Program or Career Pathways Innovation Fund, and Education’s proposed First in the World Initiative.
4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.	
Action	Agency and Estimated Cost
Sponsor summer STEM learning programs for high school students.	Education as authorized in the America Competes Act (\$10m to fund about 100 projects reaching on the order of 5000 students, annually).
Expand the scope of a DOL program and focus an NSF program to encourage pathways from 2-4 year institutions.	DOL’s TAACCT Grant Program initiative or Career Pathways Innovation Fund or NSF’s Advancing Technical Education program to support community college-university or college research and design partnerships.
Establish public-private Agency-Institution-Industry partnerships to support successful STEM programs.	All STEM and education-focused Federal agencies.
Improve data provided to STEM students, parents, and the greater community on STEM education disciplines and the labor market.	<p>Department of Education should devote more resources to tracking students from high school into their careers.</p> <p>Bureau of Labor Statistics should redefine employment categories to include in “STEM” the breadth of jobs that require STEM skills.</p>
5. Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.	

PCAST STEM Undergraduate Education Working Group

Co-Chairs

S. James Gates, Jr.*

John S. Toll Professor of Physics
Director, Center for String and Particle Theory
University of Maryland, College Park

Jo Handelsman

Howard Hughes Medical Institute Professor and
Frederick Phineas Rose Professor, Molecular,
Cellular and Developmental Biology
Yale University

G. Peter Lepage

Professor of Physics
Harold Tanner Dean, College of Arts and Sciences
Cornell University

Chad Mirkin*

Rathmann Professor, Chemistry, Materials
Science and Engineering, Chemical and
Biological Engineering and Medicine
Director, International Institute for
Nanotechnology
Northwestern University

Working Group Members

Joseph G. Altonji

Thomas DeWitt Cuyler Professor of Economics
Yale University

Peter Bruns

Vice President for Grants and Special Programs
(Retired)
Howard Hughes Medical Institute (HHMI)

Carol Christ

President
Smith College

Isaac Crumbly

Associate Vice President for Career and
Collaborative Programs
Founder, Cooperative Development Energy
Program
Fort Valley State University

Emily DeRocco

President
The Manufacturing Institute
Senior Vice President
National Association of Manufacturers

Brian K. Fitzgerald

Chief Executive Officer
Business Higher Education Forum

Mark Gorenberg*

Managing Director
Hummer Winblad Venture Partners

Shirley Ann Jackson*

President
Rensselaer Polytechnic Institute

Neal Lane

Senior Fellow in Science and Technology Policy
James Baker Institute for Public Policy
Rice University

Tom Luce

Chief Executive Officer
National Math and Science Initiative

Judy Miner

President
Foothill College

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES
WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Suzanne Ortega

Senior Vice President for Academic Affairs
University of North Carolina

Ed Penhoet*

Director, Alta Partners
Professor Emeritus, Biochemistry and Public
Health
University of California, Berkeley

Calvin Phelps

National Chair
National Society of Black Engineers (NSBE)

Daniel Schrag*

Sturgis Hooper Professor of Geology
Professor, Environmental Science and
Engineering
Director, Harvard University Center for
Environment
Harvard University

Dan Schwartz

Professor
Stanford University School of Education

Candace Thille

Director of the Open Learning Initiative Carnegie
Mellon University

Staff

Danielle Evers

AAAS Science and Technology Policy Fellow

Deborah Stine

Executive Director

Writers

Steve Olson

Science Writer

Donna Gerardi Riordan

Science Writer and Policy Analyst

* PCAST member



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

www.whitehouse.gov/ostp/pcast