SCIENTIFIC MANAGEMENT REVIEW BOARD
REPORT ON PRE-COLLEGE ENGAGEMENT IN BIOMEDICAL SCIENCE

JANUARY 2015

DEPARTMENT OF HEALTH & HUMAN SERVICES • USA

NIH National Institutes of Health
Turning Discovery Into Health

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CONTENTS

EXECUTIVE SUMMARY

Recognizing that the advancement of biomedical discoveries, cures, treatments, and disease prevention interventions relies on a sustained, skilled workforce, the National Institutes of Health (NIH) has a long and successful history of providing state-of-the-art training to aspiring biomedical science professionals. Meeting the country's biomedical workforce needs requires a steady stream of highly capable, dedicated, and creative young minds prepared to tackle complex scientific and health challenges. However, alarming trends are evident in the profile of the current and rising biomedical workforce, in terms of both the preparedness and the diversity of students seeking degrees and careers in relevant fields.

Concerns about the United States' future biomedical workforce and its ability to address the increasingly complex nature of biomedical research must be addressed. Today's biomedical workforce does not reflect the nation's rapidly changing demographic profile, and the U.S. pre-college science, technology, engineering, and mathematics (STEM) education system is grappling with widening achievement gaps. Globally, U.S. students are falling behind their peers; international tests show that students in the United States consistently rank below average in mathematics and science literacy, in contrast to marked gains by Asian and European students.[1] Within the American pre-college student population, education disparities are harming millions of students, especially underrepresented minorities[2] and the financially disadvantaged. Though many such students enter undergraduate institutions with an expressed intent to pursue a career in science, math, or engineering, few emerge with STEM degrees. The root causes of these disparities are complex and include not only challenged socioeconomic environments but also inconsistent pre-college STEM curricula and a concentration of the most prepared and talented science teachers in environments already rich in resources, with far fewer qualified teachers in schools that have a greater share of students from underrepresented and low–socioeconomic status (SES) populations. Taken together, these social and educational challenges perpetuate the lack of diversity among students entering careers in biomedical sciences.

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[1] Organisation for Economic Co-operation and Development. (2014). *PISA 2012 results: what students know and can do, volume 1.* Retrieved from http://www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-I.pdf.

[2] Underrepresented minorities are defined by the National Science Foundation as "women, persons with disabilities, and three racial/ethnic groups—blacks, Hispanics, and Native Americans… because they constitute smaller percentages of science and engineering degree recipients and of employed scientists and engineers than they do of the population." National Science Foundation. (2013). *Women, minorities, and persons with disabilities in science and engineering: 2013.* Retrieved from http://www.nsf.gov/statistics/wmpd/2013/pdf/nsf13304_digest.pdf.

Many public and private entities are trying to turn the tide to prevent the development of a future U.S. biomedical workforce that may lack both preparedness and diversity. As the largest public funder of biomedical research in the United States, NIH has an opportunity to take a leadership position. NIH's early career training programs make it the pre-eminent resource for cultivating the biomedical workforce at the graduate and postdoctoral stages. Although pre-college biomedical education is not NIH's primary mission, NIH's imprimatur may serve to galvanize work in new directions in pre-college STEM training. The unique expertise in biomedical science embedded within NIH and NIH's influence with leading research institutions affords it the opportunity to catalyze efforts to interest young students in biomedical science. NIH already has a significant number of investments in this area, with over 240 programs and activities directed at pre-college students and their teachers that represent de facto models for engaging all students—especially underrepresented minorities—in biomedical science. The expertise and guidance acquired by those leading successful NIH programs can be used to inform all stakeholders in the STEM education environment about how to best inspire and prepare America's youth to pursue a wide array of biomedical science careers.

This report, produced in response to a directive from the NIH Director, provides advice on how NIH can maximize its influence in pre-college biomedical science engagement. The Scientific Management Review Board (SMRB) encourages NIH to take a long-range, forward-thinking, targeted approach to conducting its pre-college STEM activities. The success of this effort may have implications for the scientific and economic future of this country.

Given the importance of pre-college STEM preparation for successful entry to the biomedical sciences and the dearth of underrepresented minorities in a substantial number of existing but uncoordinated NIH efforts targeting pre-college STEM education, the SMRB begins this report with an **overarching recommendation:**

NIH pre-college STEM activities need a rejuvenated, integrated focus on biomedical workforce preparedness, with special considerations for underrepresented minorities.

To that end, SMRB members recommend the establishment of an oversight body, committed to pre-college STEM education, with strong, galvanizing leadership and with representation from all relevant NIH Institutes, Centers, and Offices, as well as non-NIH stakeholders. This multidisciplinary body, formulated and resourced according to the judgment of the Director, should make recommendations directly to the Office of the Director. The oversight body should develop plans for and oversee implementation of the following activities:

- Develop a uniform reporting template of NIH-sponsored pre-college STEM programs;
- Create and maintain an inventory of all such programs;
- Develop evaluative criteria to gauge the programs' success;
- Develop optimum processes for the functionality of all current and planned programs; and
- Coordinate these programs with other federally supported pre-college STEM activities.

Findings and recommended next steps for NIH

In this report, SMRB members offer the following steps to optimize NIH's pre-college programs, supported by key findings and recommendations to NIH:

Step A. Focus pre-college efforts on the most pressing workforce needs.

Key Finding #1: There are limited opportunities for underrepresented minority and low-SES students to engage in biomedical science education.

Recommendations

- Better target NIH-funded education outreach to students from underrepresented groups and their teachers.
- Promulgate best practices of exemplary programs that have a track record of directing underrepresented minority students toward careers in biomedical science.
- Use demonstrably successful NIH enrichment programs (e.g., summer internship programs) as opportunities to enhance diversity.
- Closely monitor the outcomes of NIH's nascent undergraduate underrepresented minority recruitment, mentoring, and training programs (National Research Mentoring Network [NRMN] and Building Infrastructure Leading to Diversity [BUILD]) to determine whether these strategies could also be employed with middle and high school students and their teachers.

Key Finding #2: It is important to broaden workforce categories as a way to convey the full range of career options to pre-college youth who might consider careers in biomedicine.

Recommendations

- Emphasize the wide range of current and future career options in biomedical sciences available to all students.
- Promote the cross-disciplinary nature of innovative biomedical science.
- Coordinate NIH's STEM education programs with the work of the NIH Division of Biomedical Research Workforce Programs, in order to:
  - o Understand the composition of the current biomedical workforce;
  - o Project future workforce needs; and
  - o Identify emerging skills that should be fostered in pre-college education settings.

Step B. Coordinate and cultivate effective programs and approaches.

Key Finding #3: NIH has a large portfolio of pre-college STEM activities that could be streamlined and enhanced through increased coordination.

Recommendations

- As set forth in the SMRB's overarching recommendation, NIH should establish an oversight body to develop plans for coordinating, monitoring, and systematically evaluating NIH's pre-college activities (see page 2).
- The oversight body should emphasize efforts to:
  - Strongly encourage all NIH-supported STEM education programs to increase outreach to underrepresented populations;
  - Identify best practices and expand exemplar programs;
  - Identify resources to be provided to those engaged in teaching or mentoring pre-college students; and
  - Provide an infrastructure and process to enable curriculum developers to identify and collaborate with subject matter experts at NIH.

Key Finding #4: There are no standard measures of success for the existing NIH pre-college STEM activities. A more rigorous evaluation process may strengthen all activities and produce new best practices.

Recommendations

- Identify and track the development of STEM education best practices and evaluation standards.
- Define successful outcomes (to include careers listed under the broader definition of the biomedical workforce).
- Develop the metrics needed to evaluate the effectiveness of extant NIH STEM programs.
- Apply systematic and comparable evaluation practices for NIH's pre-college programs.
- As the evidence base for pre-college STEM education grows, determine the feasibility of expanding evaluation metrics to include measures of long-term program effectiveness.
- Work with other agencies and organizations to improve the collection of longitudinal, student-level data, especially as they relate to pre-college students' exposure to biomedical and human health learning experiences and eventual career trajectories.

Step C. Leverage strengths of the public and private sectors.

Key Finding #5: There is untapped potential in NIH's research community.

Recommendations

- Increase the impact and reach of STEM education efforts by leveraging existing investments in university researchers, trainees, and infrastructure.
- Encourage and incentivize STEM education outreach by offering supplemental funding to grantee institutions, researchers, and trainees to provide educational outreach, including summer internships, research seminars, science fairs, and especially hands-on science experiences.
- Communicate the importance of pre-college student and teacher engagement, especially directed at low-SES and underrepresented minority students, as a cultural value of the biomedical research community. These principles should be endorsed by NIH leadership, including all NIH Institute and Center (IC) directors.

Key Finding #6: There are many opportunities to partner with other entities that are committed to pre-college STEM outreach.

Recommendations

- Seek opportunities to provide expertise and guidance to and learn from private and nonprofit organizations that support pre-college programs and biomedical science outreach.
- Monitor the activities of the National Science and Technology Council's Committee on STEM Education (CoSTEM) subcommittees, especially those devoted to improving the diversity of science students and trainees and improving preschool through 12th-grade (P-12) STEM instruction.
- Leverage NIH's expertise to support governmentwide efforts to improve STEM education and strengthen the evidence base.
- Provide expertise to the Department of Education (ED) and the National Science Foundation (NSF) as they develop and implement evaluation standards for STEM programs.
- Partner with ED and NSF to improve data collection at the undergraduate and pre-college level that will be useful for biomedical workforce analysis.

Improving NIH's outreach to students and teachers in pre-college educational environments comes at an opportune time: NIH has recently redoubled its efforts to enhance the diversity of its college and postgraduate trainees through the Enhancing the Diversity of the NIH-Funded Workforce program. The agency can maximize the success of these programs with smart, targeted investments in the pre-college space.

I. INTRODUCTION

The National Institutes of Health (NIH) Reform Act of 2006 (Public Law 109-482) reaffirmed certain organizational authorities of agency officials to (1) establish or abolish national research institutes; (2) reorganize the offices within NIH's Office of the Director, including adding, removing, or transferring the functions of such offices or establishing or terminating such offices; and (3) reorganize divisions, centers, or other administrative units within an NIH national research institute or national center, including adding, removing, or transferring the functions of such units, or establishing or terminating such units. The Reform Act also established the Scientific Management Review Board (hereinafter the SMRB or the Board) to advise the NIH Director and other appropriate agency officials on the use of these organizational authorities and identify the reasons underlying the recommendations.

This report distills the deliberations and findings of the SMRB and provides recommendations to NIH regarding how the agency can optimize activities aimed at engaging pre-college students in biomedical science. NIH charged the SMRB with recommending ways to optimize these activities such that they both align with the NIH mission and ensure a continued pipeline of biomedical science students and professionals. SMRB members were asked to take the following steps:

- Examine the evidence base for successful approaches for pre-college biomedical science programs aimed at strengthening the biomedical workforce pipeline;
- Identify the attributes, activities, and components of effective pre-college biomedical science programs, including the role and relative importance of teacher training programs;
- Identify those points in the pre-college biomedical workforce pipeline where NIH's efforts could be applied most effectively, given finite resources; and
- Define ways for NIH to improve the evidence base for effective pre-college biomedical science programs.

SMRB members who formed the Working Group on Pre-college Engagement in Biomedical Science provided updates to and solicited input from the entire SMRB during its public deliberations on March 25, 2014; May 7, 2014; July 7, 2014; October 14, 2014; and December 15, 2014. During SMRB and Working Group meetings, members heard from experts and stakeholders in pre-college engagement in biomedical research (Appendix A). Consultants included NIH program officials, representatives from nonprofit education programs, science teachers, experts in education program evaluation, and experts in STEM education and career disparities.

II. BACKGROUND ON THE STATE OF PRE-COLLEGE STEM EDUCATION AND ENGAGEMENT IN BIOMEDICAL SCIENCE

Spurred by the Cold War and the launch of the Sputnik satellite by the Soviet Union, the mid-20th century was a time of unprecedented interest in math and science careers among U.S. youth. This interest was further enhanced by increased attention to and investments in science, technology, engineering, and mathematics (STEM) education at all levels of government and in the private sector. As a result, the United States has been dominant in science and technology for many decades.[3]

Challenges to U.S. STEM education

Today, however, this dominance is threatened. As some European and Asian economies have increased their research and development spending as a share of gross domestic product (GDP), U.S. expenditure has stagnated.[4] Compounding this decline, pre-college STEM education in the United States is in need of serious reform. The U.S. government will invest $2.9 billion in pre-college STEM education in FY 2015,[5] yet American students lag behind many of their international counterparts in average test scores, and this achievement gap continues to widen.[6] In 2012, the Program for International Student Assessment (PISA) conducted an evaluation of 15-year-olds' performance in reading, math, and science in 65 countries.[7] Among the 34 member countries of the Organisation for Economic Co-operation and Development (OECD), U.S. student performance was average in science and

[3] Dean, C. (2007, September 25). When science suddenly mattered, in space and in class. *The New York Times*. Retrieved from http://www.nytimes.com/2007/09/25/science/space/25educ.html.

[4] Organisation for Economic Cooperation and Development (OECD). (2014). *Main science and technology indicators*. Retrieved from stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB.

[5] Office of Science and Technology Policy. (2014). *Progress report on coordinating federal science, technology, engineering, and mathematics (STEM) education*. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/STEM-ED_FY15_Final.pdf.

[6] Center on International Education Benchmarking. (2014, March 6). Trends in the performance of the top performers on PISA 2003-PISA 2012, *Statistic of the Month*. Retrieved from http://www.ncee.org/2014/03/statistic-of-the-month-trends-in-the-performance-of-the-top-performers-on-pisa-2003-pisa-2012/.

[7] OECD. (2014). *PISA 2012 results: what students know and can do, volume 1*. Retrieved from http://www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-I.pdf.

reading and below average in math, in which the U.S. ranked approximately 26th. Even America's top math students—those in the 90th centile—ranked below the average students in Shanghai.[8]

U.S. STEM educators face numerous challenges. The uneven distribution of skilled science teachers and resources is well documented. These educational disparities harm millions of students, especially those from low-income households and underrepresented minority groups. As noted by the National Science Foundation (NSF), "Women, persons with disabilities, and three racial/ethnic groups—blacks, Hispanics, and Native Americans—are considered underrepresented in science and engineering because they constitute smaller percentages of science and engineering degree recipients and of employed scientists and engineers than they do of the population."[9] The Board learned that lower academic and career expectations often plague underrepresented minority students, and there are wide-ranging state- and local-level discrepancies in the rigor of pre-college science standards and quality of science curricula. At a time when the demographic profile of the U.S. student-age population is increasingly racially and ethnically diverse, and more than half of college students are female, this trend is especially troubling for the future of the nation's research and development capacity. Efforts to address these discrepancies are often controversial. These issues and many more will only be solved when political and community leaders, policy makers, and other decision makers at all levels of government coalesce around sound strategies and principles.

Urgent calls to improve U.S. STEM education have come from many different quarters. For example, in their 2007 report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* the National Academies recommended several steps for improving pre-college science and mathematics education, including strategies to recruit and strengthen the skills of science teachers and several tactics for creating opportunities and incentives for middle and high school students to obtain advanced STEM training.[10]

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[8] OECD. (2014). *PISA 2012 Result in Focus,* 2014. Retrieved from http://www.oecd.org/pisa/key-findings/pisa-2012-results-overview.pdf.

[9] National Science Foundation. (2013). *Women, minorities, and persons with disabilities in science and engineering: 2013.* Available at http://www.nsf.gov/statistics/wmpd/2013/pdf/nsf13304_digest.pdf.

[10] Institute of Medicine, National Academy of Sciences, and National Academy of Engineering. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* Washington, DC: The National Academies Press, 2007.

The federal response

National leaders are beginning to respond to these calls. The Obama administration has placed a high priority on STEM education, launching the Educate to Innovate initiative, a nationwide effort that includes over $700 million in public-private investments, in 2009. Congress has responded to the challenge by enacting the America COMPETES Act of 2007 and reauthorizing it in 2010.[11] Much of the act focuses on strengthening pre-college STEM education. For example, the 2010 reauthorization includes a directive to the White House Office of Science and Technology Policy to establish a committee that will coordinate federal programs and activities in support of STEM education. As a result, the Committee on Science, Technology, Engineering, and Math Education (CoSTEM), a committee of the National Science and Technology Council, was established in 2011.[12] In 2013, CoSTEM issued a five-year strategic plan that outlined a number of national goals for improving STEM education. The five major goals of the plan are to (1) improve preschool through grade 12 (P-12) STEM instruction; (2) increase and sustain youth and public engagement in STEM; (3) enhance STEM experience among undergraduate students; (4) better serve groups historically underrepresented in STEM fields; and (5) design graduate education for tomorrow's STEM workforce. These goals are being implemented through the recently constituted Federal Coordination in STEM Education Task Force (FC-STEM, a sub-committee of CoSTEM), which consists of representatives from 14 federal agencies.[13]

These nationwide efforts are focused on STEM education broadly and therefore include all federal agencies with scientific research portfolios. Given its mission to promote the progress of science in general, the NSF plays a leading role, as does the Department of Education (ED), whose mission is to promote student achievement and preparation for global competitiveness by fostering educational excellence and ensuring equal access.

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[11] The full title of the American COMPETES Act is the American Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act, P.L. 110-69.

[12] The NSTC is a Cabinet-level Council and is the principal means within the executive branch of the U.S. government to coordinate science and technology policy across the diverse entities that make up the federal research and development enterprise.

[13] FC-STEM participating agencies and organizational divisions include the Department of Agriculture, the Department of Commerce, the Department of Defense, the Department of Education, the Department of Energy, the Department of Health and Human Services (including NIH), the Department of Homeland Security, the Department of the Interior, the Department of Transportation, the Environmental Protection Agency, the Executive Office of the President, the National Aeronautics and Space Administration, the National Science Foundation, and the Smithsonian Institution.

The role of NIH in STEM education

As the largest public funder of biomedical research in the United States, NIH has an important role to play in these efforts to improve STEM education. NIH's continued success in alleviating disease and disability for all Americans and people around the globe depends upon a robust, diverse, and skilled biomedical research workforce now and in the future, so one of the agency's stated goals is to "develop, maintain, and renew the biomedical scientific workforce."

Recognizing the importance of developing and sustaining a world-class biomedical workforce, NIH makes substantial investments in scientific training. Given the complexity and degree of specialization required for biomedical research, most of this investment is directed toward the later stages of the educational pipeline, supporting young scientists at their post-baccalaureate, predoctoral, postdoctoral, and early investigator stages. NIH's investment in specialized training in the biomedical sciences is unique, since the vast majority of graduate students and postdoctoral fellows in the United States are supported through a combination of NIH training grants, fellowships, and research project grants.[14]

NIH also recognizes that in order to ensure a continued robust and skilled workforce, interventions to engage youth in the biomedical sciences must also occur earlier in the educational experience. The research that drives current and future advances in health requires not only a quality education on STEM core subjects, it increasingly relies upon advanced problem-solving skills, excellent communication, and the ability to analyze large amounts of complex information. A number of other public and private players invest in pre-college STEM education, so NIH's role in engaging students during these years is substantially smaller. Because biomedical research encompasses more advanced and applied concepts in the biological and behavioral sciences, NIH's pre-college STEM education investments are primarily targeted at youth in middle school and high school, as well as their teachers, rather than at students in the primary grades.

[14] Biomedical Research Workforce Working Group, The Advisory Committee to the Director. (2012). *Biomedical Research Workforce Working Group Report.*

The purpose of this report

As careful stewards of the public's investment in biomedical research, NIH regularly seeks to assess the effectiveness of its efforts to develop the biomedical workforce and to forecast future needs. In 2011, NIH Director Francis Collins charged the Advisory Committee to the Director (ACD) with examining the current workforce and recommending ways to strengthen NIH's approach toward workforce development. Two reports were published in 2012: one that examined the diversity of the biomedical workforce,[15] and one that focused on modeling the current and future workforce.[16] The reports identified several areas in which NIH could strengthen its investment in young scientists at the college, pre-doctoral, and postdoctoral levels. The scope of those initial reports did not include NIH's pre-college STEM education efforts, but the importance of attracting and cultivating the interests and abilities of America's pre-college youth became a common refrain during ACD deliberations.

The NIH Director subsequently charged the SMRB with articulating what role NIH should play in pre-college engagement in the biomedical sciences. While NIH is not the driving force in this area, the weight and reach of NIH is substantial; local communities across the country are home to an extraordinary network of NIH-funded scientists and clinicians. In keeping with NIH's mission to foster the next generation of America's biomedical workforce, this report offers potential strategies and leverage points that NIH can use to spark young people's interest in biomedical science and, ultimately, draw them into careers in the biomedical and related health and medical fields.

Although this report is intended for the NIH Director, the findings, recommendations, and, especially, the landscape survey represent important information for all stakeholders committed to pre-college STEM education and preparation of the biomedical workforce. Educational organizations, science organizations, community groups, and parents may find the information helpful.

[15] Working Group on Diversity in the Biomedical Research Workforce, The Advisory Committee to the Director. (2012). *Report of the Advisory Committee to the Director Working Group on Diversity in the Biomedical Research Workforce.*

[16] Biomedical Research Workforce Working Group, The Advisory Committee to the Director. (2012). *Biomedical Research Workforce Working Group Report.*

III. FINDINGS AND RECOMMENDATIONS

The current and projected biomedical workforce

Key Finding #1: There are limited opportunities for underrepresented minority and low–socioeconomic status (SES) students to engage in biomedical science education.

The advancement of biomedical discoveries, cures, treatments, and disease preventive interventions relies on a sustained, skilled biomedical workforce. In considering the current state of the workforce, SMRB members focused on three factors: the number of professionals entering biomedical science careers, the quality of those professionals' training and preparedness, and whether the group reflects the diverse composition of American society.

Determining whether there is a sufficient supply of graduate students and postdoctoral fellows entering the biomedical workforce pipeline is difficult, because many factors that must be weighed, including economic factors (e.g., levels of funding available through public and private sources) and scientific opportunities (e.g., the demand for computational biologists who can analyze huge data sets and model complex biological phenomena). SMRB members found that there was no consensus on the optimal size of the biomedical workforce: Some experts consider the workforce inadequate for the challenges of the future,[17] while others maintain that U.S. investment in scientific training has produced more scientists than the biomedical enterprise is capable of absorbing.[18]

Assessing the quality and preparation of individuals entering the biomedical workforce is also difficult and is likely to vary greatly across the disciplines and job categories encompassed by the biomedical sciences. Members of the current biomedical workforce need an increasingly sophisticated and nuanced view of the myriad determinants of health amid the growing pervasiveness of science and technology in U.S. society and the world. Yet, although the United States spends the highest percentage of GDP on higher education,[19] levels of U.S. educational attainment in 25- to 34-year-olds are lower than those in Norway, the Netherlands,

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[17] Institute of Medicine, National Academy of Sciences, and National Academy of Engineering. (2007). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* Washington, DC: The National Academies Press.

[18] Alberts B, Kirschner MW, Tilghman S, Varmus H. (2014). Rescuing US biomedical research from its systemic flaws. *Proceedings of the National Academy of Science 111:5773-5777.*

[19] National Science Board. (2012). Higher education in science and engineering. Retrieved from http://www.nsf.gov/statistics/seind12/c2/c2s4.htm.

Denmark, South Korea, and New Zealand.[20] As noted previously by the ACD, traditional conceptualizations of the biomedical workforce have focused narrowly on academic investigators. Without a broader conceptualization of cross-disciplinary scientific needs and a more comprehensive definition of what constitutes a career in biomedical science, as well as related health and medical fields and pre-college education, it is difficult to assess the quality of the workforce and define future needs.

What is unambiguously clear, however, is that the biomedical research workforce is decidedly lacking in diversity, especially in leadership positions. In 2012, NIH asked the ACD to examine NIH's track record for supporting a diverse workforce and recommend ways to address disparities in funding. The ACD focused on NIH's undergraduate and postgraduate activities and reported that black applicants were significantly less likely to receive NIH research funding than were white applicants, even after the data were controlled for education, country of origin, training, employer characteristics, previous research awards, and publication record.[21] Figure 1, reprinted from the ACD's final report, shows that compared to the makeup of the overall U.S. population, American Indian or Alaska Natives, Blacks or African Americans, Hispanics or Latinos (of any race), and Native Hawaiian and other Pacific Islanders represent a disproportionately small component of NIH-funded investigators. In 2010, Hispanics or Latinos made up 16.3 percent of the U.S. population but represented only 3.5 percent of NIH-funded principal investigators, and Blacks or African Americans made up 12.6 percent of the population but only 1.1 percent of NIH-funded principal investigators.

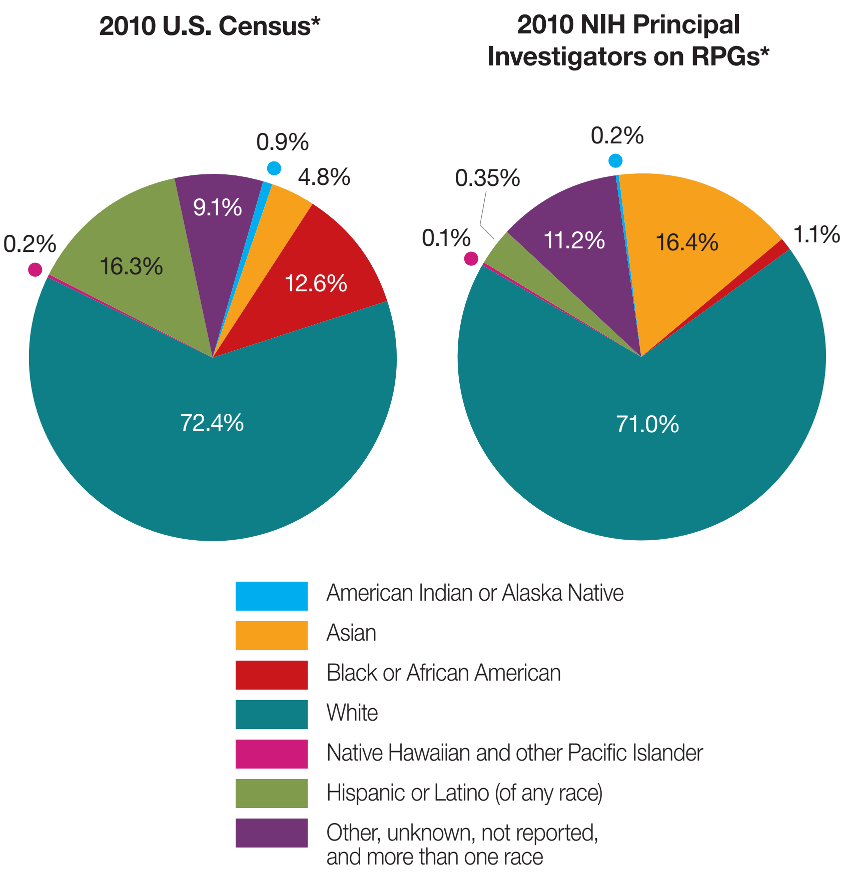
The ACD offered numerous recommendations at the undergraduate level that were aimed at increasing the number of underrepresented minorities in the workforce pipeline, including strategies to improve evaluation of NIH's training programs, enhance mentoring and career preparation for underrepresented minority trainees, provide more support to under-resourced institutions, and reduce bias in the merit review of research and training applications.[22] In response, NIH has a launched number of initiatives to increase workforce diversity, including the Building Infrastructure Leading to Diversity (BUILD) initiative, the National Research Mentoring Network (NRMN), and the Coordinating and Evaluation Center, which

[20] National Science Board. (2012). Higher education in science and engineering. Retrieved from http://www.nsf.gov/statistics/seind12/c2/c2s4.htm.

[21] Working Group on Diversity in the Biomedical Research Workforce, The Advisory Committee to the Director. (2012). *Report of the Advisory Committee to the Director Working Group on Diversity in the Biomedical Research Workforce.*

[22] Working Group on Diversity in the Biomedical Research Workforce, The Advisory Committee to the Director. (2012). *Report of the Advisory Committee to the Director Working Group on Diversity in the Biomedical Research Workforce.*

Figure 1: Race and ethnicity of the 2010 U.S. population and the 2010 NIH principal investigators on research project grants (RPGs)



2010 U.S. Census Bureau Report, http://www.census.gov/2010census/data (left)
NIH Principal Investigators on RPGs, NIH IMPAC II (right).

*Total percentage is over 100 because those identified as Hispanic/Latino may also have identified as other races. PI information collected by NIH includes the option for an applicant to signify both race and ethnicity.

will serve both the BUILD and NRMN grantees. These programs are aimed at attracting and retaining underrepresented minority students in undergraduate and graduate education programs. If successful, the programs could serve as models for engaging and retaining pre-college students.

The lack of diversity in the biomedical workforce is not unique; it is endemic to all areas of science and some other career paths. The ACD also cited evidence showing that individuals from underrepresented minority groups are less likely to receive undergraduate and graduate STEM degrees, including those in biological sciences, chemistry, and physics.[23]

Research has shown that this disparity in engagement in science begins early. Across gender and racial/ethnic groups, young students' attitudes toward STEM are positive, but STEM performance among underrepresented racial/ethnic minorities begins to lag early on, and the performance gap grows larger over time. Underrepresented minorities declare undergraduate STEM majors in the same proportion as the majority students do, but fewer remain in those academic disciplines,[24] due in large part to poor high school preparation, as well as to the broader trend of minorities leaving college without a degree.[25] Gender differences also persist. Girls earn higher grades than boys in STEM coursework overall and take advanced courses at similar rates, but middle school girls express less positive attitudes about STEM than boys do. Once in college, women commit to certain STEM majors (e.g., engineering, computer sciences, mathematics, statistics) at lower rates, but they are as likely as men complete STEM majors once they have made a choice.[26]

Stakeholders identified a range of potential levers for addressing disparities in early STEM education, including increasing access to qualified teachers, role models of potential careers, rigorous curricula, advanced coursework, extracurricular programs, resources, supplies, and infrastructure. Technology used both inside and outside of the classroom might help bridge access gaps. The program effectiveness of any intervention should be consistently and rigorously evaluated. Program developers and managers should also keep in mind that student retention is strongest with long-term, sustained STEM programs that engage families and peers.

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[23] National Science Foundation. (2011). *Women, minorities, and persons with disabilities in science and engineering: 2011.* (Tables 5.7 and 7.4, reporting 2000-2008 data). Available at http://www.nsf.gov/statistics/women/.

[24] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2011). *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads.* Washington, DC: The National Academies Press.

[25] Hrabrowski FA. (2011). Boosting minorities in science. *Science 331:* 125.

[26] National Science Foundation. (2013). *Women, minorities, and persons with disabilities in science and engineering: 2013.* Retrieved from http://www.nsf.gov/statistics/wmpd/2013/pdf/nsf13304_digest.pdf.

A key goal of NIH's STEM programs should be to engage and retain students from underrepresented populations and provide them with experiences that will encourage them to enter and succeed in the biomedical research workforce. NIH could use its leverage to introduce young students to biomedical science, provide hands-on educational opportunities for interested students and teachers, and attract and retain the interest of students from diverse backgrounds. NIH-funded education outreach should be targeted to students from underrepresented minority groups, students who would not otherwise be exposed to biomedical science, and teachers from schools with a large share of underrepresented minority students or low-SES students.

As noted previously, many other organizations are involved in pre-college STEM engagement. NIH should identify and promulgate best practices of exemplar programs that target underrepresented minorities and have demonstrated a track record of directing students toward careers in the biomedical science workforce, either via effective studies and job training in the technical and support services field or via successful matriculation at the undergraduate level with a focus on careers in biomedical science. One such program, the Stanford Medical Youth Science Program, has had considerable success in training, mentoring, and supporting low-income and underrepresented minority high school students and their parents. Another example is the state-level Junior Academies of Science and their national association, affiliated with the American Association for the Advancement of Science (AAAS), which attract many high school students, including minorities, to mentor relationships, research competitions, and in-depth experience annually at the AAAS national meetings.

Recommendations for NIH

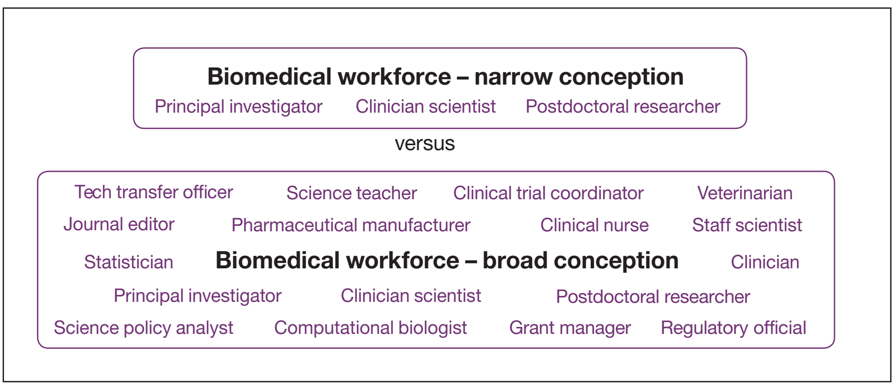
- Better target NIH-funded education outreach to students from underrepresented groups and their teachers.
- Promulgate best practices of exemplar programs with a track record of directing underrepresented minority students toward careers in biomedical science.
- Use demonstrably successful NIH enrichment programs (e.g., summer internship programs) as opportunities to enhance diversity.
- Closely monitor the outcomes of NIH's nascent undergraduate underrepresented minority recruitment, mentoring, and training programs (NRMN and BUILD) to determine whether these strategies could also be employed with middle and high school students and their teachers.

Key Finding #2: A broadening of workforce categories is important to convey the full range of career options to pre-college youth who might consider careers in biomedicine.

The current conceptualization of the biomedical science workforce, especially in academic training environments, is narrowly focused on principal investigators and clinical scientists. However, the biomedical science sector constantly evolves new job categories and opportunities for young people to engage in more cross-disciplinary science and other emerging areas of research, education, and implementation.[27] This puts a premium on teaching and learning experiences that recognize and anticipate these changes. Just as the ACD concluded in its Biomedical Workforce report, the SMRB also feels that the cross-disciplinary nature of innovative biomedical science and the wide range of current and future career options available to students should be emphasized and promoted.[28]

NIH has the standing to encourage a definition of career paths in the biomedical sciences that is broader than principal investigators, clinician scientists, and postdoctoral researchers (Figure 2). There is a need to influence popular perceptions of STEM careers and increase support in the biomedical science community for teaching, mentoring, and providing educational opportunities for pre-college students. NIH can advance this cause by embracing related activities as successful outcomes of NIH-funded training programs and projects.

Figure 2: Conceptualizations of workforce categories in the biomedical science enterprise



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[27] Alberts B, Kirschner MW, Tilghman S, Varmus H. (2014). Rescuing US biomedical research from its systemic flaws. *Proceedings of the National Academy of Sciences 111:*5773-5777.

[28] Biomedical Research Workforce Working Group, The Advisory Committee to the Director. (2012). *Biomedical Research Workforce Working Group Report.*

One important offshoot of the ACD Biomedical Workforce report was the establishment of a new office dedicated solely to workforce analysis and strategy development, the NIH Division of Biomedical Research Workforce Programs (DBRWP). NIH's pre-college STEM education programs should be informed by the work of the DBRWP, which is currently building its capacity to measure the supply, demand, and racial/ethnic/gender makeup of the biomedical workforce. Information about workforce composition and the demand for certain skills and knowledge can be used to inform the development and priority setting of pre-college programs.

Recommendations for NIH

- Emphasize the wide range of current and future career options available to students.
- Promote the cross-disciplinary nature of biomedical science.
- Coordinate NIH's STEM education programs with the work of the NIH Division of Biomedical Research Workforce Programs in order to:
    - Understand the composition of the current biomedical workforce;
    - Project future workforce needs; and
    - Identify emerging skills that should be fostered in pre-college education settings.

NIH's pre-college engagement portfolio in relation to the pre-college STEM education evidence base

As part of the charge to prioritize the most cost-effective uses of NIH's resources for attracting young people to careers in the biomedical sciences, the SMRB asked NIH Institutes and Centers (ICs) to provide information on Fiscal Year (FY) 2013 programs and activities aimed at pre-college students and their teachers. The resulting inventory is subject to reporting variances and represents only a snapshot of NIH's diverse investment in pre-college education, but it illustrates the breadth, depth, and variety of NIH's programming in this arena.

The inventory tallied 246 programs and activities across 25 ICs. The largest share (48 percent; n = 117) of these activities is grant awards made from 15 ICs to extramural institutions (see Figure 3). Most of these awards (n = 87) are resource grants for education projects geared toward increasing understanding of biomedical research, providing training, and/or creating programs that disseminate scientific discoveries to the public. Such grants support a variety of projects designed to, for example, enhance teachers' skills through summer research immersion experiences; use food, diet, and nutrition to teach basic research, science, and math concepts to middle school students; and employ common ciliate protozoa as a focal point to teach high school students the relationships between science, biotechnology, and society. A small number of awards (n = 5) were made under the Small Business Innovative Research (SBIR) mechanism, which is meant to stimulate research with the potential for commercialization. These grants support the development of neuroscience-focused education tools, such as interactive case studies, videogames, learning kits, and other interactive media.

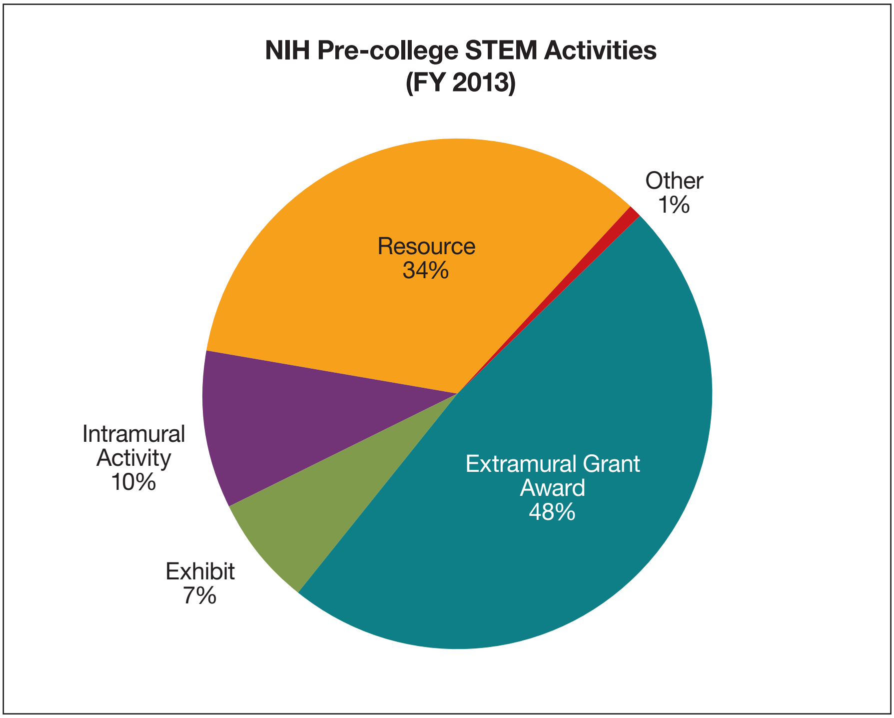
Active intramural projects make up 10 percent (n = 24) of the inventory, and over half (n = 14) offer teachers and students opportunities for hands-on experience with biomedical research in the laboratories of the NIH Intramural Research Program. Other inventoried intramural projects include outreach programs in which NIH intramural scientists directly engage students in after-school activities, adopt-a-school programs, or science festivals. Half (n = 12) of the inventoried intramural programs are focused on direct engagement of students from underrepresented groups.

Another 34 percent (n = 84) of programs and activities are resources maintained or provided by ICs through their Web sites or clearinghouses, such as a blog for teens that focuses on drug abuse science and news; repositories of educational materials on topics such as eye health, biotechnology, genetics and genomics, and neuroscience; and 19 curriculum supplements on topics ranging from mental illness to bioethics.

The remaining inventoried activities include exhibits at science museums and other venues (7 percent; n = 18) and other activities, such as the development of science fair awards (2 percent; n = 3).

NIH invests primarily in activities geared toward middle school (grades 6–8) and high school (grades 9–12) students, with 61 percent (n = 149) of activities focused exclusively on middle and high school students. When all inventoried activities *involving* (but not limited to) middle or high school students are tallied, that number rises to 83 percent (n = 203). Only 7 percent (n = 16) of inventoried activities are focused exclusively on students at grade 5 or below.

Figure 3: Distribution of inventoried biomedical STEM educational activities, by activity type[29]



These programs are evaluated in a variety of ways, including summary reports, milestone reports, surveys, interviews, and use statistics or reporting (e.g., Web analytics). While ICs reported that the majority (71 percent; n = 175) of the inventoried activities are evaluated in some manner, there is no predominant or standard method for conducting such evaluations. Inventoried activities that included no reported evaluation typically consisted of curriculum supplements, brochures, exhibits, and videos.

[29] Inventoried activities are for FY 2013 only. Intramural activities are those undertaken by NIH staff and under the mission and budget of each IC. Extramural grant awards are made to non-NIH research facilities through NIH's Extramural Research Program. Exhibits include online, traveling, and museum-based exhibits created by ICs. Resources encompass those materials or assets (e.g., curriculum supplements and Web-based educational materials) that are made publically available by the NIH ICs. While these resources are currently available, they were created during prior fiscal years via intramural projects or through prior extramural grant awards.

The pre-college STEM education evidence base

As a key element of the SMRB's charge, and to assess the current state of NIH's existing pre-college activities, SMRB members examined the evidence base for successful pre-college biomedical science programs. They intended to identify the approaches that have proven effective at preparing and attracting pre-college youth for biomedical science education and careers. However, there is little empirical evidence on which specific methodologies or educational approaches are effective, either for improving science teaching or student learning outcomes. As a case in point, the Department of Education (ED) routinely and systematically identifies studies that provide credible and reliable evidence of the effectiveness of educational practices, rating the rigor of such studies and publishing their independent assessments online in the What Works Clearinghouse.[30] Of the more than 8,000 research studies on educational intervention that ED reviewed and rated, only 32 studies examined interventions to improve science learning, and only three of those interventions have been rated "potentially effective."[31]

Although the evidence base is thin, pre-college education practitioners and evaluators did offer SMRB members information about a number of promising practices that may prove effective in the long run. In many cases, real-world research experiences appear to be pivotal for getting and keeping students' and teachers' interest in biomedical science. Technology and mobile resources have shown promise in increasing access to research experiences. The importance of sustained outreach and mentorship, rather than one-off, short-term activities, was also emphasized during consultations with experts and during SMRB and Working Group deliberations. Finally, simply surveying undergraduate students regarding what sparked their interest in science may provide ideas worth testing in NIH's portfolio.

Well-trained, highly motivated, teachers who have sufficient resources are key to engaging pre-college students in the sciences. The most effective way to bring experiential learning to students may be through their teachers, who should be provided the time, resources, and training to incorporate hands-on science learning

[30] The What Works Clearinghouse is curated by the Department of Education's Institute of Education Sciences (IES) and provides independent review of education research. Available at http://ies.ed.gov/ncee/wwc/.

[31] Per online search of the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) on December 2, 2014. Based upon a number of assessment factors, the What Works Clearinghouse uses a six-point effectiveness rating scale: positive, potentially positive, mixed evidence, no discernible evidence, potentially negative, and negative.

both inside and outside the classroom. Moreover, scientists and the universities who support them should seek opportunities in local school districts to demonstrate the importance of biomedical research to students and teachers and to emphasize its role in improving health.

One large-scale, multiyear experience in recruiting highly motivated teachers to K-12 classrooms in many of the most disadvantaged communities in the country is Teach for America (TFA). The program has grown over more than 20 years to place 5,000 college graduates, selected from more than 50,000 applicants each year, in dozens of urban areas, several rural areas, and several Native American nations. Diversity and STEM education have been major emphases for years. In the 2014 TFA teacher cohort, 50 percent identify as people of color, including 22 percent who are African-American and 13 percent who are Latino; 47 percent are Pell Grant recipients; and 34 percent are first-generation college students. Twenty percent of TFA teachers in 2014 majored in a STEM subject in college, and 33 percent teach math or science (many economics and finance majors are qualified to teach math). NIH could examine the STEM experience that programs TFA have had as potentially models for change in pre-college STEM training (correspondence with TFA vice president for recruitment David M. Omenn) (see Appendix C).

In the longer term, building up the evidence base will require rigorous research on effective pre-college STEM education practices, as well as more data about students, schools, teachers, interventions used, and outcomes. Schools and universities, faced with tight budgets and short timeframes, may not collect the data necessary to create an evidence base or follow students' educational outcomes, let alone their career outcomes. The state of the art in educational practice and evaluation is evolving, and governmental and private entities are working hard to strengthen the STEM education evidence base. Together, ED and NSF are leading in the development of standards for evaluating educational research programs. In August 2013, the two agencies co-published *Common Guidelines for Education Research and Development*.[32] The guidelines are designed to improve the quality, coherence, and pace of research in STEM education. NSF has also been working to identify and disseminate effective approaches in pre-college STEM learning. In

[32] For more information, see http://ies.ed.gov/pdf/CommonGuidelines.pdf.

2011, NSF commissioned the National Research Council (NRC) to publish a report, *Successful K-12 STEM Education;*[33] in a follow-up study in 2013, the NRC laid out a set of metrics for tracking the implementation of successful STEM programs.[34] Metrics included indicators of students' knowledge and access to quality learning, educators' capacity, and the number of material investments made by federal, state, and local entities in pre-college STEM education. As these efforts continue to mature and advance, NIH should apply best practices developed by ED and NSF to its own pre-college STEM activities.

Key Finding #3: NIH currently has a large portfolio of pre-college STEM activities that could be streamlined and enhanced through increased coordination.

NIH supports a number of biomedical STEM programs targeted at students and teachers in grades 6 through 12 (e.g., Science Education Partnership Awards, summer research programs), but these efforts are largely ad hoc and uncoordinated across the NIH. The suite of current NIH programs lacks both a central reporting structure and a common infrastructure to ensure accountability.

By providing a viewpoint from which to address NIH-wide needs and opportunities, enhanced coordination and consolidation would enable NIH to maximize the effectiveness of its STEM activities. NIH could improve coordination of its STEM activities by taking a complete inventory of its current and planned pre-college biomedical STEM programs. Metrics to assess the effectiveness of extant NIH STEM programs need further development. This report should serve as a dynamic repository with periodic updates and re-assessments.

Routine tracking and assessment of all relevant NIH activities would better equip NIH to optimize existing efforts so that they advance NIH's STEM education engagement goals, are scalable, and follow current and emerging best practices. Improved assessment activities will help determine, for example, whether NIH should direct more resources to those engaged in teaching or mentoring students in grades 6 through 12 and whether NIH is maximizing each activity's outreach to underrepresented and low-SES populations.

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[33] National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics.* Washington, DC: The National Academies Press.

[34] National Research Council. (2013). *Monitoring progress toward successful K-12 STEM education: a nation advancing?* Washington, DC: The National Academies Press.

Recommendations for NIH

- NIH should establish an oversight body focused on pre-college STEM education, with strong leadership and with representation from all relevant NIH Institutes, Centers, and Offices and non-NIH stakeholders.
- This oversight body should develop plans for and oversee implementation of the following activities:
  - Developing a uniform reporting template of NIH-sponsored pre-college STEM programs;
  - Creating and maintaining an inventory of all programs;
  - Developing evaluative criteria to gauge the success of these programs (see specific recommendations in the next section);
  - Developing optimum processes for the functionality of all current and planned programs; and
  - Coordinating these programs with other federally supported pre-college STEM activities.
- The oversight body should emphasize efforts to:
  - Strongly encourage all NIH-supported STEM education programs to maximize outreach to underrepresented populations;
  - Identify best practices and expand exemplar programs;
  - Identify resources to be provided to those engaged in teaching or mentoring pre-college students; and
  - Provide an infrastructure and process to enable curriculum developers to identify and collaborate with subject matter experts at NIH.

The SMRB recognizes that no single NIH office has an exclusive interest in the state of the biomedical workforce and the engagement of U.S. youth in the biomedical sciences; many NIH divisions have a stake in engaging students and diversifying the workforce. A structure that provides centralized coordination of these various efforts will enhance their effectiveness.

Key Finding #4: There are no standard measures of success for the existing NIH pre-college STEM activities. A more rigorous evaluation process may strengthen all activities and produce new best practices.

Closely related to the need for greater coordination is the need for standard measures of performance. The variety of evaluative methods evidenced in our inventory speaks to a key challenge of the STEM education enterprise: the lack of strong, evidence-based criteria by which to gauge effectiveness. While it is possible to measure aspects of program implementation and certain short-term outputs of funded activities, the current inability to relate these short-term outputs to long-term STEM education outcomes (e.g., STEM aptitude, interest, undergraduate and graduate retention, and career trajectories) inhibits sound decision-making for future directions. SMRB members heard from education experts, who reported that there is little evidence indicating what works in STEM education. Without such evidence, it is impossible to precisely define the attributes of effective STEM education programs and thus create a common evaluative standard for NIH's STEM education activities (both within and outside of classroom settings).

Another challenge in evaluating NIH's pre-college activities is their placement. A significant number of NIH's inventoried activities fall under the category of "informal science," is loosely defined as science education activities outside of the formal academic setting and outside of preparation for standardized college admissions tests. Examples of informal science include science fairs, mobile laboratories, and science-oriented television programs like "Sesame Street" and "CSI: Crime Scene Investigation." These engaging programs and hands-on opportunities leave lasting impressions on children. However, informal science is nearly impossible to evaluate, because of the difficulties in attributing long-term outcomes to any one of many informal science experiences. Informal science activities are often short-term and are often not hosted in venues that collect detailed participant data. Standard formal evaluations may show no outcome, which may lead evaluators to conclude that there has been no effect and possibly resulting in the termination of an effective program (discussion with COSMOS Corporation president Robert K. Yin, September 24, 2014).

Despite the challenges faced in implementing evidence-based programs and evaluating the overall effectiveness of its pre-college STEM education activities, there are opportunities for NIH to improve. In the near term, NIH can identify and broadly adopt a set of common assessment metrics to capture core defining characteristics of its pre-college activities. For example, best practices can be applied to measure factors related to implementation (e.g., whether the program was implemented as planned), intervention characteristics (e.g., what type of intervention it is and who the target population is), and short-term results (e.g., how many people were served and whether participants were more interested in pursuing biomedical coursework or career paths as a result). As illustrated in the inventory of current NIH pre-college programs and activities, many of these factors are being measured already, albeit inconsistently. In particular, given the importance of increasing underrepresented minorities' participation in the biomedical workforce, NIH should consistently assess the demographic characteristics of participants and analyze any demographic differences in short-term results (e.g., the likelihood of taking STEM courses increases for female participants but decreases for male participants).

Devising strategies to gauge the long-term effectiveness of NIH's pre-college efforts will take more time and will need to be implemented in stages as the evidence base grows. NIH will need to monitor the progress of other agencies and organizations as they build the evidence base for STEM education. Relevant offices within NIH should also continue to keep abreast of and contribute to the literature regarding what interventions work, as well as continue efforts to link pre-college student data with information about the biomedical research workforce. ED's What Works Clearinghouse will be a critical resource for tracking the growth of the STEM education evidence base over time. Eventually, NIH should expand appropriate metrics and outcome measures and improve the collection of student-level data so that successful programs can be studied and replicated. As its evaluation capacity grows, NIH should consider the feasibility of requiring regular, consistent evaluation of pre-college engagement programs to determine their impact, effectiveness, and scalability. Based on this information, NIH would be in the best position to consider rebalancing its education portfolio to respond to evaluation results and address program priorities.

Recommendations for NIH

- Identify and track the development of STEM education best practices and evaluation standards.
- Define successful outcomes (to include careers listed under the broader definition of the biomedical workforce, as shown in Figure 2).
- Develop metrics needed to evaluate the effectiveness of extant NIH STEM programs.
- Apply systematic and comparable evaluation practices for NIH's pre-college programs.
- As the evidence base for pre-college STEM education grows, determine the feasibility of expanding evaluation metrics to include measures of long-term program effectiveness.
- Work with other agencies and organizations to improve the collection of longitudinal, student-level data, especially as they relate to pre-college students' exposure to biomedical and human health learning experiences and eventual career trajectories.

Maximizing the impact of NIH's pre-college STEM investments

Key Finding #5: There is untapped potential in NIH's research community.

SMRB members determined that leveraging NIH's existing network of funded research centers offers an effective and cost-efficient opportunity to increase NIH's impact on pre-college engagement in biomedical science. NIH supports more than 300,000 research personnel at over 2,500 universities and research institutions. NIH's reach is extensive: NIH-funded universities and institutions can be found in every U.S. state and territory. In addition, about 6,000 scientists work in NIH's own Intramural Research laboratories, which are located in Bethesda, Baltimore, and Frederick, Maryland; Research Triangle Park, North Carolina; and Hamilton, Montana. Many NIH-funded universities, investigators, and trainees already devote time and resources to teaching, tutoring, mentoring, and providing hands-on research experiences to pre-college students and teachers. NIH should continually identify effective, scalable programs at U.S. universities that can be highlighted and emulated around the country.

For example, SMRB members learned about the Stanford Medical Youth Science Program (SMYSP),[35] which is supported by NIH and other public and private sources. The program offers university- and school-based science education programs for low-income and underrepresented minority high school students, their parents, and teachers across California. It has emerged as a national model for enriching and diversifying scientific and health professions. NIH could expand the reach of such effective activities and find more ways to encourage researchers and trainees to engage in educational outreach and provide youth with genuine research experiences. To encourage innovation, NIH should avoid overly prescriptive guidelines regarding outreach activities.

In developing and testing such promising practices, NIH should consider providing support for supplemental educational materials to increase students' access to hands-on research experiences, such as high-tech classrooms and mobile laboratories. NIH could use various mechanisms to encourage research universities to engage in outreach to local schools, such as adopting a local school and opening university research facilities to the school's students and teachers. Such an approach would expose students to functioning laboratories and active scientists and might lead to more opportunities for interaction between scientists, students, and teachers. NIH itself has summer research programs for students and teachers, but more sustained investments and year-round STEM outreach may be needed.

[35] For more information, see http://smysp.stanford.edu/.

At a broader level, the biomedical research community needs to make pre-college student outreach part of its culture. Such a culture change would place role models, ambassadors for science, and potential mentors in the lives of students and teachers across the country. For example, Leroy Hood, co-founder of the Institute for Systems Biology, and his colleagues and trainees are engaged with the public schools in Pasadena and, for the past 20 years, Seattle.[36] The Institute's education and outreach program offers professional development training for K-12 science teachers and has an internship program for high school students interested in lab experience. A greater commitment to pre-college outreach would likely also elevate teaching as a career option for trained scientists. It is important to note that increasing the number and quality of science teachers can be effective only if schools hire and retain these teachers, prioritize science, and give teachers adequate classroom time and resources, including resources for hands-on learning.

Recommendations for NIH

- Increase the impact and reach of pre-college STEM education efforts by leveraging existing investments in university researchers, trainees, and infrastructure.
- Encourage and incentivize STEM education outreach by offering supplemental funding to grantee institutions, researchers, and trainees to provide educational outreach, including summer internships, research seminars, science fairs, and hands-on science experiences.
- Communicate the importance of pre-college student and teacher engagement, especially that directed at low-SES and underrepresented minority students, as a cultural value of the biomedical research community. These principles should be endorsed by NIH leadership, including all IC directors. The community should be encouraged to:
    - Engage pre-college students and teachers in science enrichment activities;
    - Elevate teaching as a career option for trainees; and
    - Provide opportunities for researchers and trainees to provide sustained, long-term mentorship to pre-college students and teachers.

[36] For more information, see http://www.systemsbiology.org/isb-education.

Key Finding #6: There are opportunities for partnerships with other entities that are committed to pre-college STEM outreach.

Many institutions and organizations recognize the importance of engaging students in STEM education to prepare them for careers in the increasingly competitive global economy. Because NIH's unique strength is its expertise in biomedical research, NIH needs to seek opportunities to share that expertise with the many other public and private organizations engaged in outreach to pre-college students and teachers. NIH and other groups could improve the coordination of their collective efforts, with the goal of complementing each other's roles and influencing audiences beyond what a single organization could reach, thus achieving greater impact than working in isolation.

There are a growing number opportunities for NIH to capitalize on mutual interests in the private and nonprofit sectors. SMRB members learned about numerous STEM efforts spearheaded by nongovernmental organizations, including biomedical and pharmaceutical companies, medical and health research professional societies, and philanthropic organizations. One example, noted above, is the network of Junior Academies of Science, linked with AAAS, which has a deep commitment to STEM education through its Project 2061 and many other initiatives.[37] The SMRB also learned about how Amgen recognizes and provides financial support for pre-college science teachers (presentation by Amgen Foundation president Jean Lim Terra, July 7, 2014). SMRB members also gathered extensive information about how highly qualified science and math majors, many of them minorities themselves, are recruited to teach in highly disadvantaged communities by Teach For America (see Appendix C). NIH could reach out to Teach for America partners, such as the National Society of Black Engineers, to expand pre-college efforts.

Private-sector donors make significant contributions to pre-college STEM education programs. Change the Equation, a nonprofit organization formed by more than 100 U.S. chief executive officers, reported that member companies donate over $1 billion each year to STEM education programs (presentation from Change the Equation chief operating officer Claus von Zastrow, July 7, 2014). Many of these and other private-sector donors embrace pre-college science education as a core value, promote the inclusion of biomedical science in their outreach activities, and share NIH's goal of strengthening the biomedical workforce pipeline. NIH should explore ways to convene these organizations to coordinate activities, identify areas of unmet need, share best practices, and demonstrate the wide range of rewarding career paths available in the biomedical sciences.

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[37] For more information, see http://www.aaas.org/program/project2061.

With the Obama administration's elevation of STEM education as a national priority, federal investments and interagency coordination have expanded in recent years. ED and NSF are responsible for the largest share of federal STEM education programs, many of which fund research to identify what works in STEM instruction.[38] As discussed earlier, both groups are leading efforts to improve the STEM evidence base and develop evaluation practice approaches and guidelines. NIH should monitor those efforts closely.

NSF is also the lead federal entity for collecting data on post-secondary STEM education and career outcomes. The data collected by NSF's Center for Science and Engineering Statistics is used to identify the composition of the biomedical workforce and to reveal long-term workforce trends, but there may be opportunities to enhance and expand these data sets. For example, NIH would benefit from having more granular data on the many types of careers specifically involved in biomedical research, as well as the types of individuals who fill those positions. Moreover, strategies to link longitudinal data on pre-college student education with existing data on post-secondary STEM education and the workforce would provide a powerful resource for tracking whether national efforts are improving STEM education and long-term retention in STEM careers.

The interagency Committee on Science, Technology, Engineering, and Math Education (CoSTEM) offers a venue in which NIH can learn about other federal agencies' STEM programs and identify areas for collaboration. As described above, CoSTEM and its related working groups (collectively called FC-STEM) are working together to implement a five-year, federal government–wide strategic plan aimed at improving STEM education and engagement from preschool through the graduate level. NIH should carefully monitor and contribute biomedical research expertise to the two FC-STEM efforts that are particularly relevant to pre-college STEM activities: one focused on improving the diversity of science students and trainees, and one on improving STEM instruction from preschool through grade 12 (P-12).

[38] Committee on STEM Education, National Science and Technology Council. (2011). *The federal science, technology, engineering, and mathematics (STEM) education portfolio.* Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/costem__federal_stem_education_portfolio_report.pdf.

Recommendations for NIH

- Seek opportunities to provide expertise and guidance to private and nonprofit organizations that support pre-college programs and biomedical science outreach, and learn from those groups' efforts.
- Monitor the activities of the CoSTEM subcommittees, particularly those devoted to improving the diversity of science students and trainees and improving P-12 STEM instruction.
- Leverage NIH's expertise to support governmentwide efforts to improve STEM education and strengthen the evidence base.
- Provide expertise to ED and NSF as they develop and implement evaluation standards for STEM programs.
- Partner with ED and NSF to improve collection of data at the undergraduate and pre-college level that will be useful for biomedical workforce analysis.

IV. CONCLUSION

The SMRB Working Group on Pre-college Engagement in Biomedical Science presented the findings and recommendations found in this report during an SMRB meeting on December 15, 2014. SMRB members endorsed the report (10 in favor; 0 opposed) and agreed that NIH should:

- Focus pre-college efforts on pressing workforce needs;
- Coordinate management and evaluation of relevant activities; and
- Partner with the biomedical research community and those already active in pre-college STEM education and outreach.

The SMRB believes that NIH can optimize its role in engaging pre-college students in biomedical science by adopting the recommendations set forth in this report.

APPENDIX A: SPEAKERS AND CONSULTANTS

- Steven Ahn, Science Teacher, Abingdon High School, Abingdon, VA
- James M. Anderson, M.D., Ph.D., Director, Division of Program Coordination, Planning, and Strategic Initiatives, NIH
- Matthew Z. Anderson, Ph.D., Postdoctoral Researcher, Molecular Microbiology and Immunology Department, Brown University
- L. Tony Beck, Ph.D., Director, Office of Science Education and Science Education Partnership Awards, Office of Research Infrastructure Programs, Division of Program Coordination, Planning, and Strategic Initiatives, NIH
- William E. J. Doane, Ph.D., Research Staff Member, Science and Technology Policy Institute
- Joan Ferrini-Mundy, Ph.D., Assistant Director for Education and Human Resources, National Science Foundation
- Kevin Finneran, Ph.D., Director, Committee on Science, Engineering, and Public Policy, National Academy of Sciences
- Megan Fisk, Science Teacher, Eastern High School, Washington, DC
- Jane Hannaway, Ph.D., Founding Director, CALDER (National Center for Analysis of Longitudinal Data in Education Research), and Vice President, American Institutes for Research (AIR)
- Gary L. Harris, Ph.D., Professor of Electrical and Computer Engineering, Associate Provost for Research, and Dean of the Graduate School, Howard University
- Carol Krause, M.A., Chief, Public Information and Liaison Branch, National Institute on Drug Abuse, NIH
- Camsie A. McAdams, M.A., Deputy Director, Office of STEM, U.S. Department of Education
- Sharon L. Milgram, Ph.D., Director, Office of Intramural Training & Education, NIH
- Talia Milgrom-Elcott, J.D., Program Officer in Urban Education and Senior Manager of STEM Teacher Initiatives at Carnegie Corporation, and Co-Founder and Lead of 100Kin10
- Lola Odukoya, Middle School Science Teacher (former elementary school teacher), Langdon Education Campus, Washington, DC
- David M. Omenn, Vice President for Recruitment, Teach For America

- Stephen L. Pruitt, Ph.D., Senior Vice President of Content, Research, and Development, Achieve, Inc.
- Brian J. Reiser, Ph.D., Professor of Learning Sciences, School of Education and Social Policy, Northwestern University
- Catherine Riegle-Crumb, Ph.D., Associate Professor, Department of Curriculum and Instruction, University of Texas at Austin
- Luci Roberts, Ph.D., Director of Planning and Evaluation, Office of Extramural Research, NIH
- Hal Salzman, Ph.D., Professor, E.J. Bloustein School of Planning and Public Policy, J.J. Heldrich Center for Workforce Development, Rutgers University
- Allison L. Scott, Ph.D., Director of Research and Evaluation, Level Playing Field Institute
- Lawrence A. Tabak, D.D.S., Ph.D., Principal Deputy Director, NIH
- Terri M. Taylor, Assistant Director for K-12 Education, Education Division, American Chemical Society
- Jean Lim Terra, President, Amgen Foundation, Amgen, Inc.
- Hannah A. Valantine, M.D., Chief Officer for Scientific Workforce Diversity, NIH
- Robert K. Yin, Ph.D., President, COSMOS Corporation
- Claus von Zastrow, Ph.D., Chief Operating Officer and Director of Research, Change the Equation

APPENDIX B: SUMMARY STATISTICS FOR NIH'S PRE-COLLEGE ACTIVITIES IN FY 2013

Table B1: Inventoried Biomedical STEM Educational Activities, by IC

	Grades P-12			Grades 6-12, exclusive*		
		URM Focus			URM Focus	
IC	**Total**	**Count**	**%****	**Total**	**Count**	**%****
CC	3	2	67	3	2	67
NCATS	1	NR		1	NR	
NCI	7	5	71	6	4	67
NCRR	1	NR		NR	NR	
NEI	12	1	8	3	1	33
NHGRI	3	NR		3	NR	
NHLBI	15	3	20	13	3	23
NIA	2	1	50	2	1	50
NIAAA	4	NR		3	NR	
NIAID	10	9	90	7	6	86
NIAMS	3	1	33	2	1	50
NIBIB	7	NR		7	NR	
NICHD	1	NR		NR	NR	
NIDA	32	1	3	19	1	5
NIDCD	3	NR		1	NR	
NIDCR	2	1	50	1	1	100
NIDDK	4	3	75	3	2	67
NIEHS	13	1	8	8	1	13
NIGMS	6	4	67	4	3	75
NIMH	6	1	17	5	1	20
NIMHD	3	3	100	3	3	100
NINDS	16	1	6	5	1	20
NINR	1	NR		1	NR	
NLM	26	2	8	13	1	8
OD	64	63	98	35	34	97
Unattributed	1	NR				
Total	**246**	**102**	**41**	**148**	**66**	**45**

Notes: Inventoried activities are for FY2013 only.
URM = underrepresented minorities. NR = None reported
*Reflect those inventoried activities that focus exclusively on grades 6 through 12.
**Percentage of P-12 activities with a URM focus.

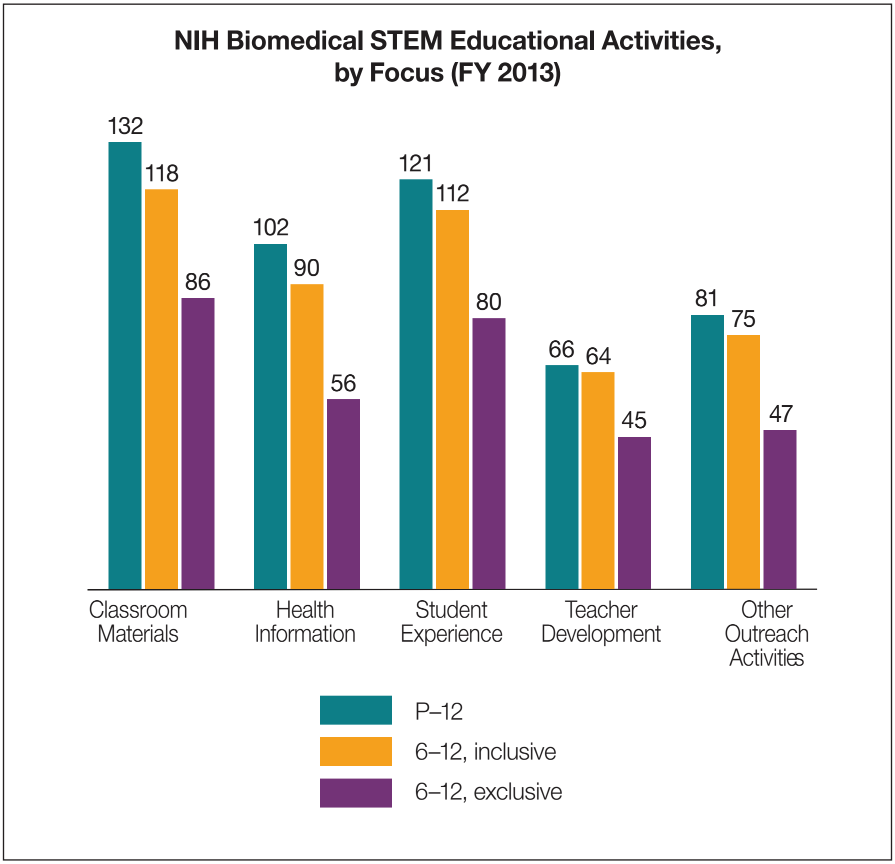
Table B2: Distribution of Inventoried Biomedical STEM Educational Activities, by Activity Type and Grade Focus

	All Activities		Grade 6-12 Activities, Inclusive		Grade 6-12 Activities, Exclusive	
Activity Type	**Count**	**%**	**Count**	**%**	**Count**	**%**
Extramural Grant Award	117	47	95	47	66	44
Exhibit	18	7	15	7	9	6
Intramural Activity	24	10	22	11	18	12
Resource	84	34	68	34	54	36
Other	3	2	2	1	2	1
Total	**246**	**100**	**202**	**100**	**49**	**99***

Notes: Inventoried activities are for FY 2013 only. Grade 6-12 activities, inclusive, reflect all inventoried activities that include, but are not limited to, students in grades 6 through 12. Grade 6-12 activities, exclusive, reflect those inventoried activities that focus exclusively on grades 6 through 12. Intramural activities are those undertaken by NIH staff and under the mission and budget of each IC. Extramural grant awards are made to non-NIH research facilities through NIH's Extramural Research Program. Exhibits include online, traveling, and museum-based exhibits created by ICs. Resources encompass those materials or assets that are made available by the NIH ICs. While these resources are currently available to the community, they were created during prior fiscal years via intramural projects *or* through prior extramural grant awards.

*Total does not add up to 100 due to rounding.

Figure B1: Focus of NIH Inventoried Biomedical STEM Education Activities, FY 2013



Notes: Inventoried activities are for FY2013 only. Activities for grades 6-12, inclusive, reflect all inventoried activities that include, but are not limited to, students in grades 6 through 12; activities for grades 6-12, exclusive, reflect those inventoried activities that focus exclusively on grades 6 through 12. Inventoried activities may be reported with multiple foci.

APPENDIX C: THE EXPERIENCE OF TEACH FOR AMERICA

Teach For America (TFA), a not-for-profit, non-federal, national organization conceived by a single college student in her thesis project in 1989, has more than 20 years of experience recruiting and placing highly motivated college graduates (and some graduate students) in K-12 classrooms in many of the most disadvantaged communities in the United States. The program now places 5,000 college graduates, selected from over 50,000 applicants each year, in dozens of urban areas, several rural areas, and several Native American nations. Diversity and STEM have been major emphases for years. In the 2014 Teacher Corps cohort, 50 percent of teachers identify as people of color, including 22 percent who are African-American and 13 percent who are Latino. In the same cohort, 47 percent are Pell Grant recipients—a proxy for lower-income background—and 34 percent are the first in their families to go to college. Twenty percent of TFA teachers majored in a STEM subject in college; 33 percent teach math or science, since many economics and finance majors are qualified to teach math. All TFA participants teach in schools where the vast majority of students come from low-income households; 90 percent of students taught by corps members are African-American or Latino. One of TFA's fundamental missions is to raise the aspirations of these children, as well as Native American children, while bringing them up to grade level.[39] Incoming teachers are provided robust training and ongoing support to ensure they develop the classroom skills to succeed. Partnering schools now seek multiple TFA placements, which provide mutual support and greater chances for children to have reinforcing experiences.

TFA launched a national STEM Initiative in 2006 to help combat the extreme shortage of qualified math and science teachers in low-income schools, partnering with organizations including Tau Beta Pi, the National Society of Black Engineers, and the American Indian Science and Engineering Society to form a coalition committed to ensuring that content experts consider teaching.

Career trajectories have been followed closely. Of 37,000 alumni, 32 percent remain in K-12 classrooms, 24 percent pursue other education-related careers (e.g., assistant principals, charter school founders, educational technology, law and policy positions), and an additional 20 percent work directly with low-income communities in other sectors. Others pursue a wide range of careers, including medical and health sciences careers, after gaining personal maturity in these challenging teaching assignments.

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[39] For more information, see http://www.teachforamerica.org/our-organization/special-initiatives/math-and-science-education-initiative-stem.

On university campuses, TFA recruitment staff meet with local chapters of Tau Beta Pi and other organizations to share the stories of teachers and alumni who have made teaching a part of a long-term path to allow them to have an impact in education, health care, and medicine. Many of the skills doctors need mirror the characteristics developed by teachers, including explaining complex topics in ways people can understand, making decisions and demonstrating judgment in moments of stress, and persevering in the face of challenge. TFA also partners with graduate schools, including medical schools and Ph.D. programs, to encourage top students to teach for at least two years before entering their programs. Corps members going into science careers are kept involved to show students positive career opportunities and to show TFA applicants that the two years of teaching enhance their career development instead of delaying it.