Scientific Management Review Board

Pre-college Engagement in Biomedical Science

Report of the SMRB Working Group on Pre-college Engagement in Biomedical Science

EXECUTIVE SUMMARY

In recognition that the advancement of biomedical discoveries, cures, treatments, and disease prevention interventions relies on a sustained, skilled workforce, 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. Alarming trends are evident, however, in the profile of the current and rising biomedical workforce in terms of both the preparedness level of the current and future biomedical workforce and the diversity of that workforce as it reflects the students seeking degrees and careers in relevant fields.

Those concerns —both in terms of demographics and skills or preparedness— of the United States' biomedical workforce of tomorrow and its ability to address the increasingly complex nature of biomedical research are especially acute. Today's biomedical workforce does not reflect the Nation's rapidly changing demographic profile and the U.S. pre-college STEM education system is grappling with widening achievement gaps. Globally, American students are falling behind their peers; international tests show students in the U.S. consistently rank below average in mathematics and science literacy, amidst marked gains by Asian and European students.[1] Within the American pre-college student population, education disparities are harming millions of students, specifically under-represented minorities and the financially disadvantaged. Though many enter undergraduate institutions with an expressed intent to pursue a career in science, math, or engineering, few emerge with STEM degrees. The root causes for this inequity are complex and include not only a challenged socioeconomic environment but also an inconsistent STEM curriculum in pre-college and a concentration of the most prepared and talented science teachers in already well-resourced environments, with far fewer qualified teachers in under-represented communities and schools. In aggregate, these social and educational challenges perpetuate the absence of diversity in those entering careers in biomedical sciences.

Many public and private entities are engaged in attempts to turn the tide of a future biomedical workforce that may be lacking in both preparedness and diversity. As the largest public funder of biomedical research in the U.S, NIH has an opportunity to take a leadership position. Its early career training programs situate NIH as the pre-eminent resource for cultivating the biomedical workforce at the graduate and post-doctoral stages of the educational and training pipeline. Though pre-college biomedical education is not the primary mission of the NIH, its imprimatur and stamp of importance

[1] OECD, *PISA 2012 Results: What Students Know and Can Do*, Vol 1, 2014, available at www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-I.pdf.

may serve to galvanize new directions in pre-college STEM training. The unique expertise in biomedical science embedded within the NIH and its strong influence with leading research institutions affords the opportunity to catalyze efforts to interest young students in biomedical science. A surprising number of extant investments of the NIH in pre-college programs, specifically greater than 240, represent de facto model templates for engaging *all* students, including—and especially—underrepresented minorities, in biomedical science. The expertise and guidance acquired by the purveyors of the successful NIH programs can be called on to inform all stakeholders in the STEM education environment as to what may best inspire and prepare America's youth to pursue a wide array of biomedical science careers.

This report, 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 the Agency to take a long-range, forward-thinking, and targeted approach in its pre-college STEM activities. The success of this effort will have implications on the scientific and economic future of this country.

Given the importance of pre-college STEM preparation for successful entry in the biomedical sciences and the striking dearth of under-represented minorities in the setting of a substantial number of existing but uncoordinated NIH efforts targeting pre-college STEM education, the SMRB begins this report with a **single overarching recommendation driven by a compelling guiding principle:**

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

To that end we recommend the establishment of a transformative body, committed to pre-college-STEM, with strong galvanizing leadership and with representation of all relevant NIH Institutes, Centers, and Offices and similarly committed non-NIH stakeholders. This multi-disciplinary body, formulated and resourced according to the wishes of the Director, should make recommendations directly to the Office of the NIH Director. The focus should address the development and oversight of the following activities:

- Development of a uniform reporting template of NIH sponsored pre-college STEM programs;
- Creation and maintenance of an inventory of all programs;
- Development of optimum processes for the functionality of all current and planned programs;
- Coordination of these programs, including synergy with other Federally supported pre-college STEM activities; and
- Development of evaluative criteria to gauge the success of these programs.

Findings and recommended next steps for NIH

In this report, SMRB members offer the following next steps supported by key findings with pertinent additional recommendations to NIH:

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

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

Recommendations:

- Better target NIH-funded education outreach to students from under-represented groups and their teachers.
- Promulgate best practices of exemplar programs with a track record of directing under-represented minority students toward careers in biomedical science.
- Utilize demonstrably successful NIH enrichment programs (e.g., summer internship programs) as opportunities to enhance diversity.
- Closely monitor the outcomes of NIH's nascent undergraduate under-represented 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: A broadening of workforce categories is important to convey 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:
  - 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.

Step B. Coordinate and cultivate effective programs and approaches:

Key Finding #3: NIH at present has a large portfolio of pre-college STEM activities. NIH should seek to streamline these activities and enhance the effectiveness of these activities through increased coordination.

Recommendations:

- As set forth in the SMRB's overarching recommendation, the NIH should establish a transformative body to develop plans for coordinating, monitoring, and systematically evaluating NIH's pre-college activities (see page 2).
- This body should emphasize efforts to:
  - Strongly encourage all NIH-supported STEM programs to increase outreach to under-represented populations.
  - Identify best practices and expand exemplar programs.
  - Identify resources to be provided to those engaged in teaching or mentoring pre-college students.
  - 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 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 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 socioeconomic status (SES) and underrepresented minorities, as a cultural value of the biomedical research community endorsed by NIH leadership, including all Institute and Center (IC) Directors:
    - 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.

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

Recommendations:

- Seek opportunities to provide expertise and guidance to private and non-profit organizations that support pre-college programs and biomedical science outreach and to learn from them.
- Monitor the subcommittee activities of the National Science and Technology Council's Committee on STEM Education (CoSTEM), in particular the subgroups devoted to improving the diversity of biomedical students and trainees and improving preschool through 12th grade (P-12) STEM instruction.
- Leverage NIH's expertise to support government-wide 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 build 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 post-graduate 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 the Office of the Director, NIH, 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, SMRB or 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:

- 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, non-profit education program representatives, 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 fueled by increased attention to and investments in science, technology, engineering, and mathematics (STEM) education at all levels of government. Coupled with a national-level “intensity and attention to science,” this investment in STEM education, together with public and private sector investments in research and development, resulted in clear U.S. dominance in science and technology for many decades.[2]

Challenges to US STEM Education

Today, however, this dominance is threatened. As the R&D intensities (expenditures in research and development as a share of GDP) in some European and Asian economies have increased, U.S. expenditure has stagnated.[3] Compounding this decline, the current state of pre-college STEM education is in need of serious reform. The U.S. government will invest $2.9 billion in pre-college STEM education in FY 2015,[4] yet American students lag behind many of their international counterparts in average test scores, and this achievement gap continues to widen.[5] In 2012, the Program for International Student Assessment (PISA) conducted an assessment of 15-year-olds' performance in reading, math, and science in 65 countries.[6] Among the 34 member countries of the Organisation for Economic Cooperation and Development (OECD), U.S. student performance was average in science and 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.[7]

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 minority and low income students. The Board also learned that lower academic and career expectations often plague under-represented minority students, and there are wide-ranging state- and local-level discrepancies in the rigor of pre-college science standards and quality of science curriculum. 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.

Calls for the pressing need to improve U.S. STEM education have come from many different quarters. For example, in its 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

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[2] Cornelia Dean, "When Science Suddenly Matter, in Space and in Class", The New York Times, September 25, 2007, available athttp://www.nytimes.com/2007/09/25/science/space/25educ.html.
[3] Organisation for Economic Cooperation and Development (OECD), *Main Science and Technology Indicators*, 2014, available at stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB.
[4] Office of Science and Technology Policy, *Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education*, March 24, 2014, available at www.whitehouse.gov/sites/default/files/microsites/ostp/STEM-ED_FY15_Final.pdf.
[5] Center on International Education Benchmarking, *Trends in the Performance of the Top Performers on PISA 2003-2012*, March 6, 2014, available at www.ncee.org/2014/03/statistic-of-the-month-trends-in-the-performance-of-the-top-performers-on-pisa-2003-pisa-2012/.
[6] OECD, *PISA 2012 Results: What Students Know and Can Do*, Vol 1, 2014, available at www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-I.pdf.
[7] OECD, *PISA 2012 Result in Focus*, 2014, available at www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf.

science teachers and several means for creating opportunities and incentives for middle-school and high-school students to acquire advanced STEM training.[8]

The Federal Response

National leaders are beginning to respond to these calls. The Obama Administration has placed a high priority on STEM education, launching in 2009 the Educate to Innovate initiative, a Nation-wide effort that includes over $700 million in public-private investments. Congress has also responded to the challenge by enacting the America COMPETES Act of 2007 and its reauthorization in 2010.[9] Much of the COMPETES Act focuses on strengthening pre-college STEM education. For example, included in the provisions of the 2010 reauthorization is a directive to the White House Office of Science and Technology Policy to establish a committee that will coordinate federal program and activities in support of STEM education. The Committee on Science, Technology, Engineering, and Math Education (CoSTEM), a committee of the National Science and Technology Council, was established in 2011.[10] 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 of 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 fourteen federal agencies.[11]

These nation-wide 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 National Science Foundation (NSF) plays a leading role, as does the Department of Education (ED), given its mission to promote student achievement and preparation for global competitiveness by fostering educational excellence and ensuring equal access.

The Role of NIH in STEM Education

As the largest public funder of biomedical research in the United States, including the biological and behavioral sciences, NIH has an important role to play in these many efforts to improve STEM education.

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[8] 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.

[9] 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.

[10] 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.

[11] 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 success of NIH in alleviating disease and disability for all Americans and around the globe depends upon a robust, diverse, and skilled biomedical research workforce now and in the future. Thus, a stated goal of the Agency 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 specificity of biomedical research, most of this investment is directed toward the latter 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 as the vast majority of graduate students and postdoctoral fellows in the U.S. are supported on a combination of NIH training grants, fellowships, and research project grants.[12]

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 their educational experience. The research that drives todays—*and tomorrow’s*—advances in health requires not only acquisition of a quality education on STEM core subjects, but increasingly relies upon advanced problem solving skills, excellent communication, and the ability to analyze large amounts of complex information. Given the number of public and private players investing in pre-college STEM education, NIH supports substantially fewer programs aimed at engaging youth in their pre-college and college years. 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 the primary grades.

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 his Advisory Committee to the Director (ACD) with examining the current workforce and recommending ways to strengthen NIH’s approach toward its development. Two reports were published in 2012, one that examined the diversity of the biomedical workforce[13] and one that focused on modeling the current and future workforce.[14] The reports identified several areas in which NIH could strengthen its investment in training 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 catching and cultivating the interests and abilities of America’s youth before college became a common refrain during the ACD’s deliberations.

The NIH Director subsequently charged the SMRB with articulating the role NIH should play in pre-college engagement in the biomedical sciences. While NIH is not the driving force in this space, the

[12] Biomedical Research Workforce Working Group, The Advisory Committee to the Director (2012). *Biomedical Research Workforce Working Group Report.*
[13] 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.*
[14] Biomedical Research Workforce Working Group, The Advisory Committee to the Director (2012). *Biomedical Research Workforce Working Group Report.*

weight and reach of NIH is substantial; local communities across the country house an extraordinary network of NIH-funded scientists and clinicians. In keeping with its mission to foster the next generation of America's biomedical workforce, this report to the NIH Director offers potential strategies and leverage points that the agency can use to spark the interest of young people in biomedical science and ultimately draw them into careers in the biomedical sciences and allied health fields.

Though this report is intended for the 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, other science organizations, community groups, and parents may find the information in this report of benefit.

III. FINDINGS AND RECOMMENDATIONS

A. THE CURRENT AND PROJECTED BIOMEDICAL WORKFORCE

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

The advancement of biomedical discoveries, cures, and treatments relies on a sustained, skilled biomedical workforce. In considering the current state of the workforce, the Working Group focused on three factors: the quantity of professionals entering biomedical science careers, the quality of their training and preparedness, and whether they reflect the diverse make-up of American society.

Determining whether there is a sufficient supply of graduate students and postdoctoral fellows entering the biomedical workforce pipeline is difficult, considering the many factors that must be weighed, such as economic factors (e.g., levels of funding available through public and private sources) and scientific opportunities (e.g., demand for computational biologists who can analyze huge data sets and model complex biological phenomena). The Working Group learned that there was no consensus on the optimal size of the biomedical workforce, hearing from some experts who feel the workforce is inadequate for the challenges of the future,[15] while others maintained that U.S. investment in scientific training has produced more scientists than the biomedical enterprise is capable of absorbing.[16]

Assessing the quality and preparation of individuals entering the biomedical workforce is also difficult, and is likely to vary greatly across the many disciplines and job categories encompassed by the biomedical sciences. Members of today's biomedical workforce must have an increasingly sophisticated and nuanced view of the myriad determinates of health amidst the growing pervasiveness of science and technology within our society and the world. Yet despite the U.S. having the largest expenditures on higher education (as a percentage of GDP),[17] levels of U.S. educational attainment in 25-34 year olds

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[15] 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.
[16] Alberts B, Kirschner MW, Tilghman S, Varmus H. *Rescuing US biomedical research from its systemic flaws*. Proc Natl Acad Sci 111: 5773–5777, 2014.
[17] http://www.nsf.gov/statistics/seind12/c2/c2s4.htm, accessed on December 11, 2014.

have been surpassed by Norway, the Netherlands, Denmark, Korea, and New Zealand.[18] As noted previously by the ACD, the Working Group found that traditional conceptualizations of the biomedical workforce have focused narrowly on academic investigators. Without a broader conceptualization of cross-disciplinary scientific needs and a more encompassing definition of careers in biomedical science, as well as allied health fields and pre-college education, it is difficult to assess the quality of the workforce and especially difficult to define future needs.

What is unambiguously clear, however, is that the biomedical research workforce is decidedly lacking in diversity, especially in positions of leadership. In 2012, NIH asked the ACD to closely examine NIH's track record in supporting a diverse workforce and recommend ways to address disparities in funding. The ACD, which focused on NIH's undergraduate and post-graduate activities, reported that: "Black applicants were significantly less likely to receive NIH research funding than were White applicants. Even after controlling for education, country of origin, training, employer characteristics, previous research awards, and publication record, a highly significant gap in success rate persisted."[19] Figure 1, re-printed from the ACD's final report, shows that compared to the make-up 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 the NIH-funded investigators.

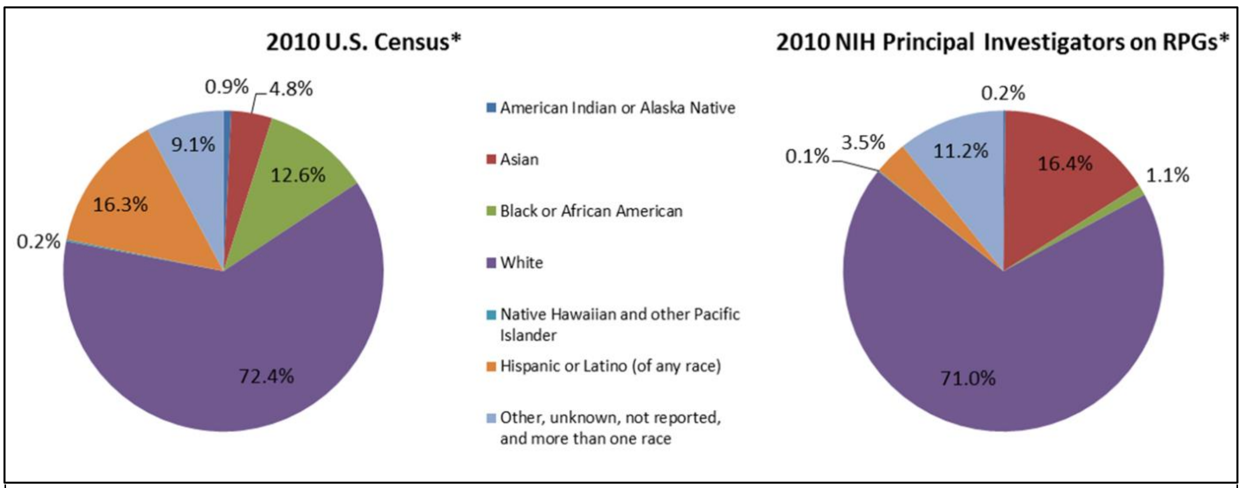

Figure 1: Race and Ethnicity of the 2010 U.S. Population and the 2010 NIH Principal Investigators on research project grants (RPGs)

***Notes**: 2010 U.S. Census Bureau Report, http://2010.census.gov/2010census/data/2010 (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.*

The ACD offered numerous recommendations at the undergraduate level aimed at increasing the number of underrepresented minorities in the workforce pipeline, including strategies to improve evaluation of its training programs, enhance mentoring and career preparation for underrepresented

[18] http://www.nsf.gov/statistics/seind12/c2/c2s4.htm, accessed on December 11, 2014.
[19] 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.*

minority trainees, provide more support to under-resourced institutions, and reduce bias in the merit review of research and training applications.[20] In response, NIH has a launched number of initiatives to increase workforce diversity, including Building Infrastructure Leading to Diversity (BUILD), the National Research Mentoring Network (NRMN), and the Coordinating and Evaluation Center (CEC) that will serve both the BUILD and NRMN grantees. These programs are aimed at attracting and retaining under-represented minority students in undergraduate and graduate education programs. If successful, they could serve as models for engaging and retaining pre-college students.

The lack of diversity in the biomedical workforce is not unique, but is endemic to all areas of science, as well as many other esteemed career paths in our society. The ACD also cited evidence that individuals from underrepresented minorities are less likely to receive undergraduate and graduate STEM degrees, including those in biological sciences, chemistry, and physics.[21] As noted by the National Science Foundation, "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."[22]

Research has shown that this disparity in engagement in science begins early in the educational pipeline. Student attitudes toward STEM are positive at a young age across gender and racial/ethnic groups, yet STEM performance of under-represented racial/ethnic minorities begins to fall behind at young ages, and the performance gap grows larger over time. Underrepresented minorities declare undergraduate STEM majors in the same proportion to the majority students, but fewer remain in these academic disciplines,[23] due in large part to poor high school preparation as well as the broader trend for minorities to leave college without a degree.[24] 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 do boys. Once in college, women enter into some STEM majors at lower rates (e.g., engineering, computer sciences, and mathematics and statistics), but are just as likely as men to persist in STEM major once chosen.[25]

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 curriculum, advanced coursework, extracurricular programs, resources, supplies, and infrastructure. Technology used both inside and outside of the classroom may bridge access gaps. And for any intervention,

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[20] 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.*

[21] National Science Foundation's "Women, Minorities, and Persons with Disabilities Report 2011" (Tables 5.7 and 7.4, reporting 2000-2008 data)

[22] National Science Foundation, "Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013," http://www.nsf.gov/statistics/wmpd/2013/pdf/nsf13304_digest.pdf

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

[24] Hrabrowski FA. *Boosting Minorities in Science*. Science; 331 (6014), p. 125, 2011.

[25] National Science Foundation, "Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013," http://www.nsf.gov/statistics/wmpd/2013/pdf/nsf13304_digest.pdf

program effectiveness should be consistently and rigorously evaluated. Program developers and managers should also keep in mind that student retention is best with long-term, sustained STEM programs and those that engage families and peers.

A key goal of NIH's STEM programs should be to engage and retain students from under-represented populations and provide them with experiences that will encourage them to enter the biomedical research workforce and be successful. NIH could use its resources and 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 those from under-represented minority groups, students who would not otherwise receive exposure to biomedical science, and teachers from schools with a large share of under-represented minority students or low SES students.

As noted, many other organizations are involved in pre-college STEM engagement, and NIH should identify and promulgate best practices of exemplar programs that target under-represented 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 is the Stanford Medical Youth Science Program, which has had considerable success in training, mentoring, and supporting low-income and under-represented minority high school students and their parents. As another example, State-level Junior Academies of Science and their national Association (AJAS), affiliated with the American Association for the Advancement of Science, 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 under-represented groups and their teachers.
- Promulgate best practices of exemplar programs with a track record of directing under-represented minority students toward careers in biomedical science.
- Utilize demonstrably successful NIH enrichment programs (e.g., summer internship programs) as opportunities to enhance diversity.
- Closely monitor the outcomes of NIH's nascent undergraduate under-represented 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: A broadening of workforce categories is important to convey 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. 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.[26] 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.[27]

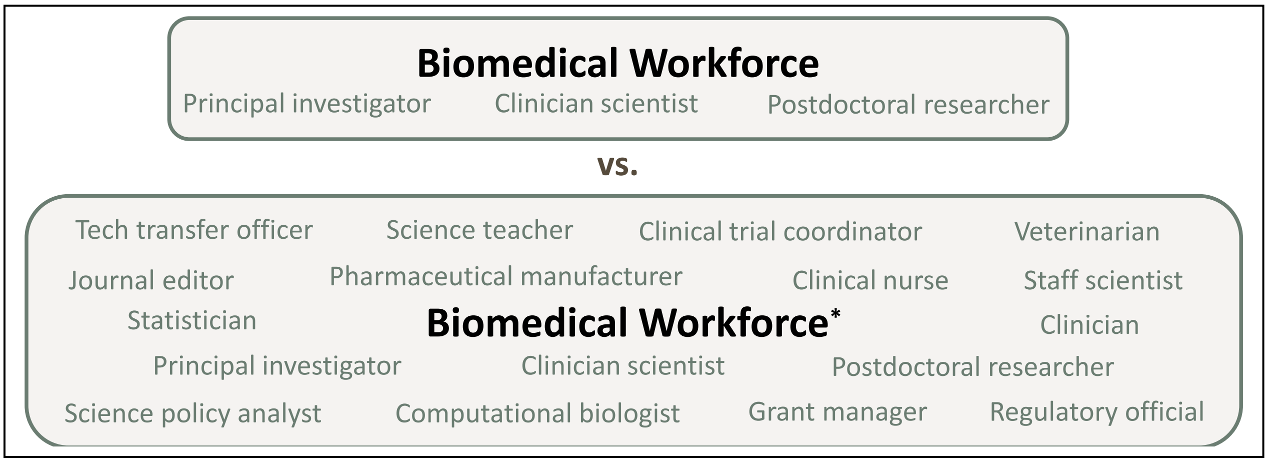

Figure 2: Outmoded Workforce Categories in the Biomedical Science Enterprise

NIH has the presence to encourage a broader definition of career paths in the biomedical sciences beyond principal investigators and clinician scientists (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 and projects.

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.

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[26] Alberts B, Kirschner MW, Tilghman S, Varmus H. *Rescuing US biomedical research from its systemic flaws*. Proc Natl Acad Sci; 111: 5773–5777, 2014.

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

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.

B. 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 efforts and 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. However, it is elucidative of 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%, n=117) of these activities are grant awards made from 15 ICs to extramural institutions (see Figure 3). Most of these (87) awards are resource grants for education projects that are 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 teacher 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 (5) of awards were made under the Small Business Innovative Research (SBIR) mechanism, 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.

Ten percent (n=24) of the inventory are active intramural projects. Over half (14) offer teachers and students opportunities to have hands-on experiences with biomedical research in the laboratories of the NIH intramural program. Other inventoried intramural projects include outreach programs in which NIH intramural scientists directly engage students in after-school, adopt-a-school, or science festivals. In addition, half (12) of the inventoried intramural programs are focused on direct engagement—ranging from summer internships to after-school programs—of students from underrepresented groups.

Another 34% (n=84) of programs and activities are resources maintained or provided by ICs through their websites 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 are exhibits at science museums and other venues (7%, n=18) and other activities (2%, n=3), such as the development of science fair awards.

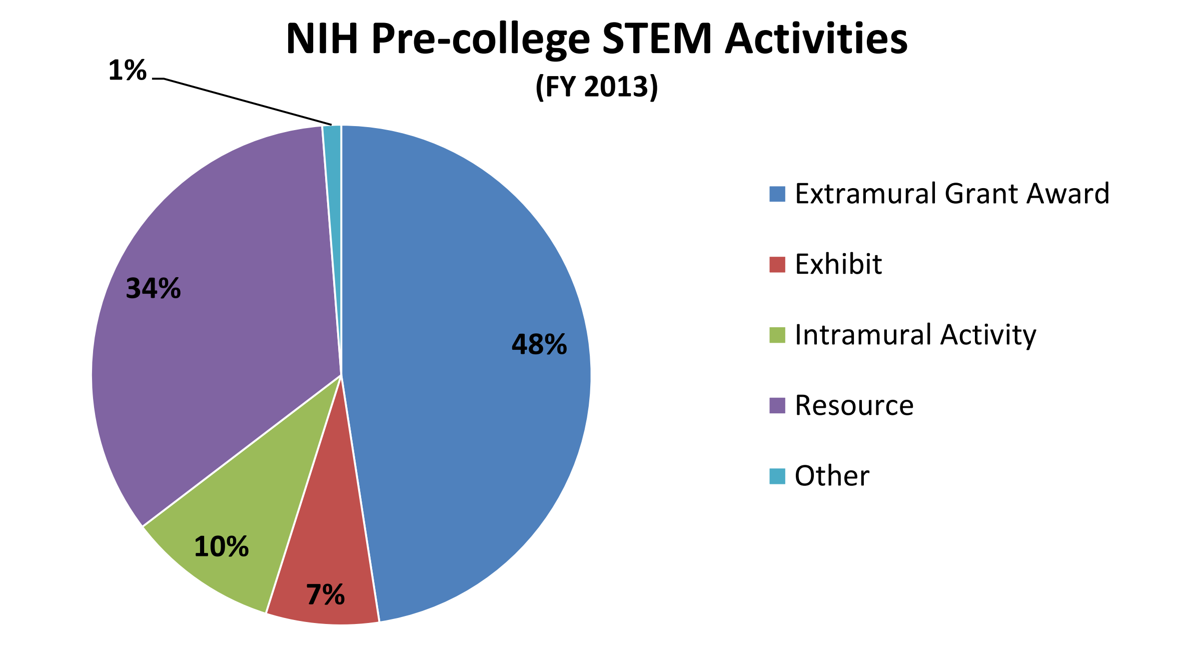

Figure 3. Distribution of Inventoried Biomedical STEM Educational Activities, by Activity Type

Notes: *Inventoried activities are for FY2013 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.*

NIH invests primarily in activities geared toward middle school (6^{th}–8^{th} grade) and high school (9^{th}–12^{th} grade) students, with 61% (n=149) of activities focused exclusively on middle and high school students. When all inventoried activities involving middle or high school students are tallied, that number rises to 83% (n=203). A minority of inventoried activities (7%, n=16) are focused exclusively on students at grade 5 or below.

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

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, the Working Group examined the evidence base for successful pre-college biomedical science programs. The intent was to identify the attributes, activities, and components of approaches that have proven effective at preparing and attracting youth in biomedical science careers. However, there is little empirical evidence on specific methodologies or educational approaches that 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 (WWC)*.[28] Of the more than 8,000 research studies on educational intervention reviewed and rated by ED, only 32 examine interventions to improve science learning, and only 3 of those interventions have been rated as "potentially effective."[29]

While the evidence-base is thin, the Working Group did hear about a number of promising practices from pre-college education practitioners and evaluators, which may prove effective in the long-run. Real-world research experiences appear, in many cases, to be pivotal for capturing and retaining the interest of students and teachers 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 in the Working Group's deliberations. Lastly, simply surveying undergraduate students regarding what sparked their interest in science may provide ideas worthy of testing in NIH's portfolio.

Well-trained, highly-motivated, and sufficiently resourced teachers 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 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 their teachers and emphasize its role in improving health.

One large-scale, multi-year experience in recruiting highly-motivated teachers to K-12 classrooms in many of the most disadvantaged communities in the U.S. is Teach for America. This program has grown over more than 20 years to place 5,000 college graduates from >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 its 2014 teacher cohort, 50% identify as people of color, including 22% African-American and 13% Latino; 47% are Pell Grant recipients; and 34% are first-generation college students. Twenty percent of TFA teachers majored in a STEM subject in college, and one-third teach

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

[29] Per online search of the What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/) conducted on December 2, 2014. Based upon a number of assessment factors, the WWC utilizes a 6-point effectiveness rating scale: Positive, Potentially Positive, Mixed evidence, No Discernible evidence, Potentially Negative, and Negative.

math or science since many economics and finance majors are qualified to teach math. NIH could examine the STEM experience of programs such as Teach for America as potentially disruptive models for change in pre-college STEM training (see Appendix C).

In the longer term, building up the evidence base will require rigorous research on effective pre-college STEM education practices and more data – about students, schools, teachers, the interventions used, and outcomes. Schools and universities, faced with tight budgets and tight timeframes, may not collect the data necessary to create an evidence base or follow students' educational outcomes, much less their career outcomes. However, the state-of-the-art in educational practice and evaluation is a moving target, and other governmental and private organizations 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 a report, *Common Guidelines for Education Research and Development.*[30] 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 2011, NSF commissioned the National Research Council (NRC) to publish a report, *Successful K-12 STEM Education*,[31] and in a follow-up study in 2013, the NRC laid out a set of metrics for tracking the implementation of successful STEM programs.[32] 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, among others. 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 at present has a large portfolio of pre-college STEM activities. NIH should seek to streamline these activities and enhance the effectiveness of these activities through increased coordination.

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

Enhanced coordination and consolidation would enable NIH to maximize the effectiveness of its STEM activities by providing a viewpoint from which to address global (NIH-wide) needs and opportunities. To better coordinate STEM activities, a complete inventory of the NIH's current and planned pre-college biomedical STEM programs is needed. The expenditures to support these programs should be collated and summed, and 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.

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[30] http://ies.ed.gov/pdf/CommonGuidelines.pdf

[31] National Research Council. *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Washington, DC: The National Academies Press, 2011.

[32] National Research Council. *Monitoring Progress Toward Successful K-12 STEM Education: A Nation Advancing?*. Washington, DC: The National Academies Press, 2013.

Aided by routine tracking and assessment of trans-NIH activities, the agency would be better equipped to optimize existing efforts across NIH such that they advance NIH's STEM education engagement goals, are scalable, and follow existing best practices. Improved assessment activities will help determine, for example, whether NIH should direct more resources to those engaged in teaching or mentoring 6^{th}-12^{th} grade students and whether NIH is maximizing each activity's outreach to under-represented and low SES populations.

<u>Recommendations for NIH:</u>

- NIH should establish an oversight body focused on pre-college STEM, with galvanizing leadership and with representation of all relevant NIH Institutes, Centers, and Offices and non-NIH committed stakeholders.
- The Steering Committee should develop plans for and oversee implementation of the following activities:
    - Development of a uniform reporting template of NIH sponsored pre-college STEM programs;
    - Creation and maintenance of an inventory of all programs;
    - Development of optimum processes for the functionality of all current and planned programs;
    - Coordination of these programs including synergy with other Federally supported pre-college STEM activities; and
    - Development of evaluative criteria to gauge the success of these programs (see specific recommendations in the next section).
- Additionally, this body should emphasize efforts to:
    - Strongly encourage all NIH-supported STEM programs to maximize outreach to under-represented populations.
    - Identify best practices and expand exemplar programs.
    - Identify resources to be provided to those engaged in teaching or mentoring pre-college students.
    - Provide an infrastructure and process to enable curriculum developers to identify and collaborate with subject matter experts at NIH.

The SMRB recognizes that no one office alone holds sole interest in the state of the biomedical workforce and the engagement of our Nation's youth in the biomedical sciences. Many NIH divisions have a stake in engaging students and diversifying the workforce. Thus a structure that provides centralized coordination will enhance success.

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 NIH's coordination needs, 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 outcomes (e.g., STEM aptitude, interest, undergraduate and graduate retention, and career trajectories) inhibits sound decision-making for future directions. There is a dearth of evidence for what works in STEM education. Without such evidence, it is impossible to precisely define the attributes of effective STEM programs and thus create a common evaluative standard for NIH's STEM education activities (both within and outside of classroom settings).

Another challenge to the evaluation of NIH's pre-college activities is their placement, in many cases, outside the formal academic setting. A sizable number of NIH's inventoried activities fall under the category of "informal science." 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. The engagement and hands-on opportunities informal science offers students are likely invaluable, leaving lasting impressions on children. However, informal science is nearly impossible to evaluate because of the difficulties in attributing long-term outcomes to what may be one of many experiences with informal science activities. Informal science activities are often short-term, and additional variables make it difficult to tease out the effects of just one activity. Standard formal evaluations may show no outcome, leading evaluators to (perhaps incorrectly) conclude that there has been no effect.

Despite the challenges faced in implementing evidence-based programs and evaluating the overall effectiveness of its pre-college STEM 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 program/activity implementation (e.g., has the program been implemented as planned?), intervention characteristics (e.g., what is the type of intervention?; who is the target population for the program/activity?), and short-term outputs (e.g., how many people were served by the program/activity?; at its conclusion, were participants more interested in pursuing biomedical coursework or career paths?). 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 the participation of under-represented minorities in the biomedical workforce, NIH should consistently assess the demographic characteristics of participants and account for differing demographics in short-term outputs.

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 a step-wise manner 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, the agency 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 NIH's evaluation capacity grows, the agency 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).
- 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 student's exposure to biomedical and human health learning experiences and eventual career trajectories.

C. MAXIMIZING THE IMPACT OF NIH'S PRE-COLLEGE STEM INVESTMENTS

Key Finding #5: Untapped potential of NIH's research community

The Working Group 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. The reach of NIH 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, located in Bethesda, Baltimore, and Frederick, Maryland, as well as in 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, the Working Group heard about the Stanford Medical Youth Science Program (SMYSP) which is supported by NIH and other public and private sources. The SMYSP offers university- and school-based science education programs for low-income and under-represented minority high school students, their parents, and teachers across California. The program has emerged as a national model for enriching and diversifying scientific and health professions. NIH could expand the reach of such model 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 student access to hands-on research experiences, such as high-tech classrooms and mobile laboratories. NIH can use various mechanisms to encourage research universities to engage in outreach to local schools, for example by adopting a local school and opening their research facilities to students and teachers. This would expose students to functioning laboratories and active scientists and might lead to more opportunities for interaction between scientists, students, and teachers. NIH has summer research programs for students and teachers, but more sustained investments and year-round STEM outreach may be needed.

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 ambassadors for science, role models, and potential mentors in the lives of students and teachers across the U.S. A widely-known example is the engagement by Leroy Hood and his colleagues and trainees with the public schools in Pasadena and for the past 20 years in Seattle. Increased commitment to pre-college outreach would likely also elevate teaching as a career option among trained scientists. It is important to note that increasing the number and quality of science teachers can only be effective 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 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 directed at low SES and underrepresented minorities, as a cultural value of the biomedical research community endorsed by NIH leadership, including all Institute and Center (IC) Directors:
    - 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.

Key Finding #6: Opportunities for partnering with other entities committed to pre-college STEM outreach

Many institutions and organizations recognize the importance of engaging students in STEM to prepare them for careers in the increasingly competitive and global economy. As NIH's unique strength is its expertise in biomedical research, the agency 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 the varied entities in this space could improve the coordination of their collective efforts with the goal of complementing each other's roles and influencing audiences beyond the reach of single organizations, thus achieving greater impact than working in isolation.

There are growing opportunities for NIH to capitalize on mutual interests in the private and non-profit sector. The Working Group learned about numerous STEM efforts spearheaded by non-governmental organizations, including biomedical and pharmaceutical industry, 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. The SMRB also learned about recognition of and financial support for pre-college science teachers from Amgen, Inc. The Working Group also gathered extensive information about the recruitment of highly qualified science and math majors, many of them minorities themselves, to teach in highly disadvantaged communities by Teach For America (see Appendix C). NIH could reach out to some of their partners, such as the Society of Black Engineers.

Some estimates suggest that the private sector is providing upwards of $1 billion in philanthropic funding for pre-college STEM education programs every year. Many of these groups 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 for the purpose of coordinating activities, identifying areas of unmet need, sharing best practices, and demonstrating the wide range of rewarding career paths.

With the elevation of STEM education as a national priority by the Obama Administration, federal investments and interagency coordination in this area 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.[33] As discussed earlier in the report, ED and NSF are leading efforts to both improve the STEM evidence base and to develop evaluation practice approaches and guidelines. Again, 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 understand the composition of the biomedical workforce and to reveal long-term workforce trends, but opportunities may exist to enhance and expand these data sets. For example, NIH would benefit from more granular data on the many types of careers specifically involved in biomedical research as well as

[33] Committee on STEM Education, National Science and Technology Council (2011). *The Federal Science, Technology, Engineering, And Mathematics (STEM) Education Portfolio*.

the types of individuals who fill those positions. Moreover, strategies to link longitudinal pre-college student education data with existing post-secondary STEM education and workforce data, would provide a powerful resource to track 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 agencies' STEM programs and identify areas to collaborate. As described above in the Introduction (Federal Landscape of Pre-College STEM activities), CoSTEM and its related working groups (collectively called FC-STEM) are working together to implement a five year, federal-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 biomedical students and trainees and the second on improving preschool through 12th grade (P-12) STEM instruction.

Recommendations for NIH:

- Seek opportunities to provide expertise and guidance to private and non-profit organizations that support pre-college programs and biomedical science outreach and to learn from them.
- Monitor the subcommittee activities of the National Science and Technology Council's Committee on STEM Education (CoSTEM), in particular the subgroups devoted to improving the diversity of biomedical students and trainees and improving P-12 STEM instruction.
- Leverage NIH's expertise to support government-wide efforts to improve STEM education and strengthen the evidence base.
- Provide expertise to ED and NSF as they build 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.

IV. CONCLUSION

To be written following vote on report by the full Board.

APPENDIX A: Speakers

Hal Salzman, Ph.D., *Professor, E.J. Bloustein School of Planning & Public Policy, J.J. Heldrich Center for Workforce Development, Rutgers University*

Stephen Pruitt, Ph.D., *Senior Vice President of Content, Research & Development, Achieve, Inc.*

Sharon Milgram, Ph.D., *Director, Office of Intramural Training & Education, National Institutes of Health*

Carol Krause, M.A., *Chief, Public Information and Liaison Branch, National Institute on Drug Abuse, National Institutes of Health*

Dr. Gary Harris, *Howard University*

Camsie McAdams, *Deputy Director, Office of STEM, U.S. Department of Education*

Robert K. Yin, Ph.D., *COSMOS Corporation*

Larry Tabak, D.D.S., Ph.D., *Principal Deputy Director, National Institutes of Health*

Hannah A. Valantine, M.D., *Chief Officer for Scientific Workforce Diversity, National Institutes of Health*

Kevin Finneran, Ph.D., *Director, Committee on Science, Engineering, and Public Policy, National Academy of Sciences*

James M. Anderson, M.D., Ph.D., *Director, Division of Program Coordination, Planning, and Strategic Initiatives, National Institutes of Health*

Steven Ahn, *High School Science Teacher, Abingdon High School, Abingdon, Virginia*

Megan Fisk, *High School Science Teacher, Eastern High School, Washington, DC*

Lola Odukoya, *Middle School Science Teacher (former elementary school teacher), Langdon Education Campus, Washington, DC*

Matthew Z. Anderson, Ph.D. *Postdoctoral Researcher, Molecular Microbiology and Immunology Department, Brown University*

Catherine Riegle-Crumb, Ph.D. *Associate Professor, Department of Curriculum & Instruction, University of Texas at Austin*

Allison Scott, Ph.D. *Director of Research and Evaluation, Level Playing Field Institute*

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*

Stephen L. Pruitt, Ph.D. *Senior Vice President, Content, Research & Development, Achieve, Inc.*

Brian J. Reiser, Ph.D. *Professor of Learning Sciences, School of Education and Social Policy, Northwestern University*

Terri M. Taylor *Assistant Director for K-12 Education, Education Division, American Chemical Society*

Jean Lim Terra *President, Amgen Foundation, Amgen, Inc.*

Claus von Zastrow, Ph.D. *Chief Operating Officer and Director of Research, Change the Equation*

Joan Ferrini-Mundy, Ph.D. *Assistant Director for Education and Human Resources, National Science Foundation*

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)*

William E. J. Doane, Ph.D. *Research Staff Member, Science and Technology Policy Institute*

Luci Roberts, Ph.D. *Director of Planning and Evaluation, Office of Extramural Research, NIH*

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*

David M. Omenn, *Vice-President for Recruitment, Teach For America*

APPENDIX B: Summary statistics for NIH's pre-college activities in FY 2013

Table B1. Inventoried Biomedical STEM Educational Activities, by, by IC

	Grades P-12			Grades 6-12, exclusive		
		URM Focus			URM Focus	
IC	**Total**	**Count**	**%**	**Total**	**Count**	**%**
Unattributed	**1**					
CC	**3**	2	67%	**3**	2	67%
NCATS	**1**			**1**		0%
NCI	**7**	5	71%	**6**	4	67%
NCRR	**1**		0%			
NEI	**12**	1	8%	**3**	1	33%
NHGRI	**3**			**3**		0%
NHLBI	**15**	3	20%	**13**	3	23%
NIA	**2**	1	50%	**2**	1	50%
NIAAA	**4**			**3**		0%
NIAID	**10**	9	90%	**7**	6	86%
NIAMS	**3**	1	33%	**2**	1	50%
NIBIB	**7**			**7**		0%
NICHD	**1**					
NIDA	**32**	1	3%	**19**	1	5%
NIDCD	**3**			**1**		0%
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**			**1**		0%
NLM	**26**	2	8%	**13**	1	8%
OD	**64**	63	98%	**35**	34	97%
Grand Total	**246**	**102**	**41%**	**148**	**66**	**45%**

Notes: *Inventoried activities are for FY2013 only. Exclusive 6th-12th grade activities reflect those inventoried activities that focus exclusively on grades 6 through 12.*

Table B2. Distribution of Inventoried Biomedical STEM Educational Activities, by Activity Type and Grade Focus						
	All Activities		6th-12th Activities, Inclusive		6th-12th 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%
Grand Total	**246**		**202**		**149**	

Notes: *Inventoried activities are for FY2013 only. Inclusive 6^{th}-12^{th} grade activities reflect all inventoried activities that include, but are not limited to, 6^{th}-12^{th} grade students. Exclusive 6^{th}-12^{th} grade activities 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.*

1

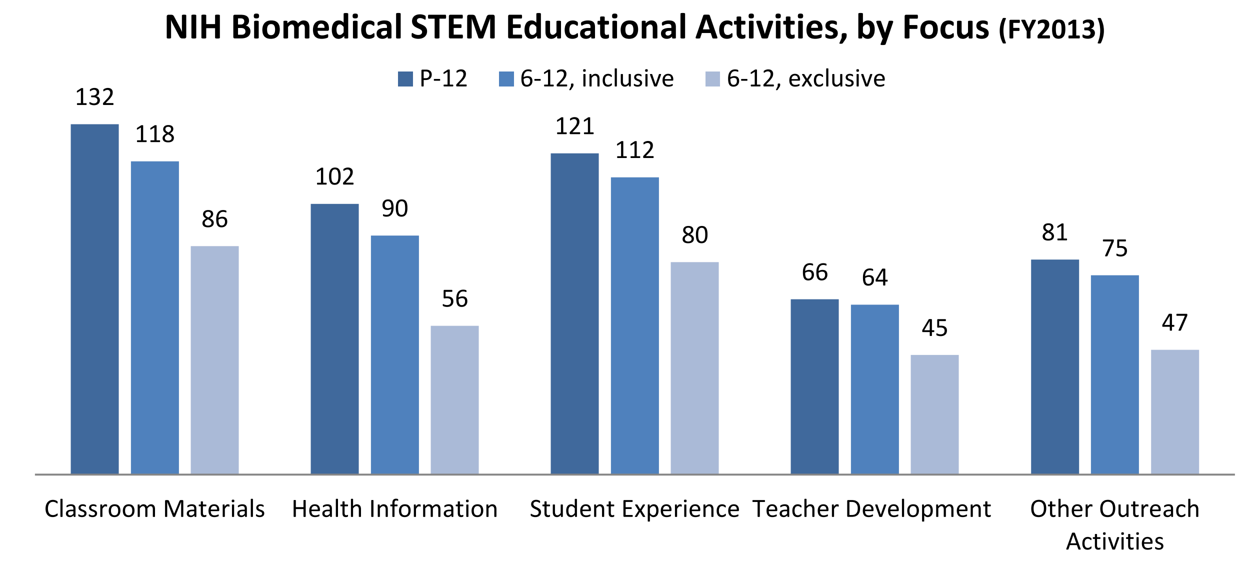

Figure B1. Focus of NIH Inventoried Biomedical STEM Education Activities, FY2013.

Notes: *Inventoried activities are for FY2013 only. Inclusive 6^{th}-12^{th} grade activities reflect all inventoried activities that include, but are not limited to, 6^{th}-12^{th} grade students. Exclusive 6^{th}-12^{th} grade activities 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 >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. This program now places 5,000 college graduates from >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 identify as people of color, including 22 percent African-American and 13 percent Latino. Forty-seven percent are Pell Grant recipients—a proxy for lower-income background—and 34 percent are first-generation college students. Twenty percent of TFA teachers majored in a STEM subject in college; 33% teach math or science since many economics and finance majors are qualified to teach math. The ethnicity reflects the total Corps. All teach in schools where the vast majority of students come from low-income households; 90% of students taught by Corps members are African-American or Latino. A fundamental mission is to raise the aspirations of these children, as well as Native American children, while catching up on grade-level.[34] Incoming teachers are provided robust training and ongoing support to ensure they obtain the classroom skills to succeed as a teacher. 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 like Tau Beta Pi, the National Society of Black Engineers, and the American Indian Science and Engineering Society to form a coalition committed to ensuring content experts consider teaching.

Career trajectories have been followed closely. Of 37,000 alumni, 32% remain in K-12 classrooms, 24% pursue other education-related careers (assistant principals, charter school founders, educational technology, law, policy), and an additional 20% 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.

On campuses, TFA staff meet with local chapters to share the stories of teachers and alumni who have made teaching a part of a long-term path of impact in education, health care, and medicine. Many of the skills doctors must possess mirror the characteristics developed by teachers: explaining complex topics in ways people can understand, making decisions and demonstrating judgment in moments of stress, persevering in the face of challenge, and more. Teach For America also partners with graduate schools, including medical schools and PhD 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 kids the positive career opportunities and show TFA applicants that the two years of teaching add to their career development instead of delaying it.

[34] http://www.teachforamerica.org/our-organization/special-initiatives/math-and-science-education-initiative-stem.