Ensuring the Next Generation of STEM Talent through K–12 Research Programming

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Summary

Labor shortages persist in the United States in a variety of STEM (science, technology, engineering, and mathematics) fields. To address these shortages, the next administration should establish a national, federally funded initiative involving the public and private sectors to develop a more robust and diverse pipeline of STEM talent. The **Next Generation of STEM Talent Through K–12 Research Programming Initiative** will remove significant barriers to participation in STEM careers through enhanced K–12 STEM programs such as science fairs and robotics competitions, as well as through strengthened federal support for teacher training to actively engage K–12 students in STEM research.

Challenge and Opportunity

Need for a Stronger STEM pipeline in the United States

A 2018 report from the National Science and Technology Council (NSTC) notes that "Since the founding of the Nation, science, technology, engineering, and mathematics (STEM) have been a source of inspirational discoveries and transformative technological advances, helping the United States develop the world's most competitive economy and preserving peace through strength."[1] Indeed, a vigorous domestic STEM workforce that innovates quickly to confront national challenges is a central driver for economic growth.[2,3] Yet while the number of degrees awarded in STEM fields has increased since 2000 in the United States,[4] labor shortages persist in certain fields requiring STEM degrees. These fields include computer science, data science, electrical engineering, and software development.[5]

In addition, the rest of the world is outpacing the United States when it comes to upper-level STEM education. The United States awarded nearly 800,000 first university degrees (i.e., associate's and bachelor's degrees) in science and engineering (S&E) in 2016, the most recent year for which data are available for the U.S. and EU.[6] However, the European Union (EU) top 6 countries (France, Germany, Italy, Poland, Spain, and the U.K., then part of the EU) produced more than 700,000 equivalent degrees—and China 1.7 million (in 2015)—around the same

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[1] National Science & Technology Council (2018). Charting a Course for Success: America's Strategy for STEM Education. Committee on STEM Education. https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf.
[2] Romer, P.M. (1990). Endogenous Technological Change. Journal of Political Economy, 98: S71–S102.
[3] Aghion, P.; Howitt, P. (1992). A Model of Growth through Creative Destruction. Econometrica, 60: 323–351.
[4] National Science Board (2020). The State of U.S. Science and Engineering 2020 | NSF - National Science Foundation, Science & Engineering Indicators. https://ncses.nsf.gov/pubs/nsb20201.
[5] Noonan, R. (2017). STEM Jobs: 2017 Update (ESA Issue Brief #02-17). Office of the Chief Economist, Economics and Statistics Administration, U.S. Department of Commerce. https://www.commerce.gov/sites/default/files/migrated/reports/stem-jobs-2017-update.pdf.
[6] National Science Board (2020). The State of U.S. Science and Engineering 2020 | NSF - National Science Foundation U.S. and Global Education Chapter 2: Higher Education in Science and Engineering, Science & Engineering Indicators. https://ncses.nsf.gov/pubs/nsb20201/u-s-and-global-education.

timeframe. The United States only awards 21% of first university degrees in science and engineering, lagging peer nations such as China (40%), Germany (35%), South Korea (33%), and the United Kingdom (30%).[7]

The data are more complex but equally worrisome at the doctorate level. According to the most recent data, the United States awarded the largest number of S&E doctoral degrees of any country (about 40,000 per year), followed by China (about 34,000); Germany, India, and the United Kingdom (about 16,000 each); and Russia (about 14,000). Together, the top six of the EU countries awarded more (about 77,000) S&E doctoral degrees than the United States.[8] Comparisons of doctoral-degree production in the United States with doctoral-degree production in other nations need to account for the fact that a substantial number of U.S. S&E doctorate recipients are students on temporary visas. However, many of these doctorate recipients stay in the United States for jobs after obtaining their degrees. Moreover, the United States also lags peer nations when it comes to the percentage of S&E doctorates awarded out of all doctorates awarded. This figure is 44% for the United States, behind China (nearly 60%), Sweden (55%), Taiwan (53%), India (50%), and the U.K. (48%).

If the United States is to keep pace and ensure continued innovation and prosperity, it must up its game on STEM education and training. The COVID-19 pandemic drives home the need for a robust STEM workforce. Scientists are racing to discover more about the virus itself and its impact, as well as to develop vaccines and treatments safely and in record time. Engineers are designing new equipment and ways to manufacture needed personal protective equipment (PPE) and ventilators. Computer scientists, statisticians, epidemiologists, and big-data scientists are collaborating to make sense of pandemic data and model outcomes to inform public-health policies. Similar crises will inevitably arise in the future. We as a nation must prepare by strengthening the STEM pipeline and closing the gap between demand for and supply of STEM talent. Because of the time and training required to become a scientist or engineer, this effort must begin without delay. This effort must also focus on creating a diverse and inclusive STEM talent pool. Only by drawing on the talents of all its citizens can the United States effectively maintain and grow the national innovation base that supports key economic sectors.

Launching the Next Generation of STEM Talent Through K–12 Research Programming Initiative

The next administration should launch the **Next Generation of STEM Talent Through K–12 Research Programming Initiative**, coordinated by the White House Office of Science and Technology Policy (OSTP) through a working group of federal agency representatives, to strengthen the STEM pipeline in the United States. The initiative would provide an additional $25 million per year for 10 years to select agencies to support K–12 research programs (such as science fairs and robotics competitions) that inspire critical thinking and encourage young people to pursue STEM careers. The new funds would also be used to train educators and community-

[7] National Science Board (2020). International S&E Higher Education. Higher Education in Science and Engineering, Science and Engineering Indicators. https://ncses.nsf.gov/pubs/nsb20197/international-s-e-higher-education.
[8] Germany, France, Poland, Italy, Spain, and the United Kingdom (then part of the EU) accounted for 75% of this number.

based scientists to become K–12 research mentors, expand research programs at the local and national levels, and build an interagency tracking mechanism to coordinate and evaluate the success of these programs. Since almost 16% of the 2.1 million federal employees in the United States occupy a STEM position, this initiative would directly benefit the Federal Government—and, by extension, U.S. civil society.[9] This initiative should also involve the private sector, as many companies and their trade associations are also in need of STEM talent and lead programs that the initiative could leverage. Only the Federal Government has the resources and infrastructure to undertake and coordinate this public-private partnership.

Inclusivity is an indispensable aspect and opportunity of this new initiative. Access to STEM education and representation in STEM fields is unequally distributed in the United States. Women, differently abled persons, and three ethnic or racial groups—Blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives—are significantly underrepresented in science and engineering education and employment.[10] As reported in the National Science Board's 2020 Science and Engineering Indicators, women make up more than half the college-educated workforce but less than 30% of the STEM workforce. Similarly, Blacks/African Americans and Hispanics/Latinos make up about 28% of the overall population but only 13% of the STEM workforce.[11] Research suggests there are many individuals—especially women, minorities, and children from low-income families—who would have developed highly impactful inventions had they been exposed to innovation in childhood.[12,13] **The Next Generation of STEM Talent Through K–12 Research Programming Initiative is designed to help find those "lost Einsteins".**

There will be an emphasis placed on rural students who do not have adequate mentors and educational systems currently in place. Studies have shown that underserved minority and rural communities often do not have access to the same educational opportunities as more affluent white communities, and this impacts the careers they will pursue.[14] This disparity has become even clearer during the novel coronavirus pandemic when schools physically closed and online teaching became the norm. The pandemic exposed the enormous gaps between the country's poorest and wealthiest schools around access to basic technology and live remote instruction, as well as the percentages of students who teachers report were not logging in or making contact.[15]

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[9] U.S. Office of Personnel Management (n.d.). Federal Workforce Data—December 2019. https://www.fedscope.opm.gov/employment.asp.
[10] National Science Foundation (2019). Women, Minorities, and Persons with Disabilities in Science and Engineering: 2019 | NSF - National Science Foundation. National Center for Science and Engineering Statistics. https://ncses.nsf.gov/pubs/nsf19304/digest.
[11] National Science Board (2020). Science and Engineering Labor Force | NSF - National Science Foundation. Science and Engineering Labor Force, Science & Engineering Indicators. https://ncses.nsf.gov/pubs/nsb20198/demographic-trends-of-the-s-e-workforce.
[12] National Science & Technology Council (2018). Charting a Course for Success.
[13] Bell, A.; et al. (2019). Who Becomes an Inventor in America? The Importance of Exposure to Innovation. The Quarterly Journal of Economics, 134(2): 647–713.
[14] Bolkan, J. (2018). Report: Rural Districts Deserve More Policy and Research Focus. The Journal, January 26. https://thejournal.com/articles/2018/01/26/report-rural-districts-deserve-more-policy-and-research-focus.aspx.
[15] Herold, B. (2020). The Disparities in Remote Learning Under Coronavirus. Education Week, April 10. https://www.edweek.org/technology/the-disparities-in-remote-learning-under-coronavirus-in-charts/2020/04.

Informal learning, especially participation in research programs such as science fairs or robotic competitions, is one way to inspire critical thinking in young people and foster long-term interest in STEM.[16] Research funded by the National Science Foundation shows that participating in a science research project increases student interest in STEM careers.[17,18] Success in this area requires training teachers to be effective research mentors. An excellent prototype for such training is the Research Teachers Conferences run by the Society for Science & the Public. The Research Teachers Conferences annually convene high-school STEM research teachers each year to share best practices, troubleshoot challenges, and establish a network of support for each other. Nearly 2,000 teachers each year request the opportunity to attend these conferences, but funding is currently only available for 200—highlighting the pent-up demand for STEM research training. More training is also needed to help professional scientists become more effective research mentors for K–12 students. and they, too, need training to ensure optimal effectiveness. **The Next Generation of STEM Talent Through K–12 Research Programming Initiative is designed to train a collaborative community of K–12 research mentors working throughout the United States.**

There are already many hands-on programs designed to increase the STEM talent pool by providing research-based and problem-solving learning opportunities to K–12 students: especially underrepresented minorities, girls, or students from rural communities. These programs range in size from small to large and in scope from local to federal. Programs are run by institutions such as nonprofit organizations, colleges and universities, scientific societies, and even industry trade associations. For example, the American Chemical Society has provided economically disadvantaged high-school students with paid summer-research internships for more than 50 years. Students participating in the internship program work under the guidance of professional scientists who have been trained to be research mentors. The Society for Science & the Public's Advocate Program provides mentors to support underserved students in submitting research projects to science competitions. Funding for these types of K–12 STEM programs comes from a myriad of sources, including philanthropic foundations and individuals, companies, and local, state, and federal governments. But there is currently no widespread coordination among these programs or sharing of best practices. There is also little rigorous evaluation to determine program success. **The Next Generation of STEM Talent Through K–12 Research Programming Initiative will provide leadership to align complementary efforts and additional funding to support assessment and scale-up of practices proven effective.**

Only the Federal Government has the ability to accomplish the three objectives outlined above. As the 2018 NSTC report states, "The Federal Government has a key role to play in furthering STEM education by working in partnership with stakeholders at all levels and seeking to remove

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[16] Hazari, Z.; et al. (2010). Connecting high school physics experiences, outcomes, expectations, physics identity, and physics career choice: A gender study. Journal of Research in Science Teaching, 47(8): 978–1003.
[17] Sawchuck, S. (2017). Are Science Fairs Worth All That Trouble? Study Seeks Some Answers. Education Week, November 6. https://www.edweek.org/teaching-learning/are-science-fairs-worth-all-that-trouble-study-seeks-some-answers/2017/11.
[18] Education Development Center, Inc. (n.d.). Science Fairs Under the 'Scope. http://sciencefairstudy.edc.org/?page_id=272.

barriers to participation in STEM careers, especially for women and other underrepresented groups." The Next Generation of STEM Talent Through K–12 Research Programming Initiative will enable the Federal Government to fill this role.

Plan of Action

The Next Generation of STEM Talent Through K–12 Research Programming Initiative should have four major components: (1) White House leadership, coordination, tracking, and evaluation; (2) federal budget commitments; (3) meaningful agency participation; and (4) partnership with non-federal organizations to provide programmatic content and complementary actions. The sections below provide more detail on each of these components, along with concrete recommended actions for the next administration.

<u>(1) White House leadership, coordination, tracking, and evaluation</u>

The next president should sign an Executive Order (EO) launching a national **Next Generation of STEM Talent Through K–12 Research Programming Initiative** led by the White House Office of Science and Technology Policy (OSTP).

The initiative would oversee and strengthen federal support for teacher training and program development designed to actively engage students in STEM research and problem-solving. The EO should also establish an OSTP-led working group modeled on the NSTC group that wrote *Charting a Course for Success: America's Strategy for STEM Education*. The working group would coordinate relevant activities across federal agencies and their subunits. Some federal agencies already have directly relevant programs in place. Other agencies could help identify offices and programs essential to the initiative's success. The working group should issue an open call for nonprofit organizations with expertise in research-based STEM learning and teacher/mentor training to participate as advisors to the working group. The working group could also include representatives from existing programs that help expand research-based and problem-solving STEM experiences at the K–12 level. The EO should task the working group with developing a strategic national action plan that includes metrics to monitor the initiative's success, as well as with creating a centralized database that can track, monitor, and evaluate programs funded by the initiative. The working group should periodically report to the Executive Office of the President on the initiative's progress.

Overall goals of the initiative would be to:

(i) Ensure an abundance of qualified applicants from a variety of backgrounds—including variety in gender, race, or socioeconomic status—for all STEM jobs in the United States.
(ii) Train teachers to provide students with research-based STEM education opportunities throughout their K–12 education experiences.

(iii) Create a comprehensive database to track programs (and their participants) aligned with and/or funded by the initiative.

(iv) Rigorously and fairly evaluate programs aligned with and/or funded by the initiative, quickly communicating evaluation findings in ways that help programs adjust to best serve students and educators.

Quantitative targets to assess progress towards these goals include:

(i) Improving the extent to which demographics of applicants to STEM jobs in the United States reflect demographics of the United States as a whole.

(ii) Availability of project-based STEM learning at publicly funded K–12 schools, as well as student access to opportunities (e.g., science fairs) where they can share the results of their work.

(iii) Grow the pool of qualified STEM research educators to 100,000 in the next 10 years, so that all schools have access to the needed number of trained educators.

(2) Federal budget commitments

A few agencies—such as the National Aeronautics and Space Administration (NASA), the National Security Agency (NSA), and the Department of Defense (DOD)—currently directly support aspects of this initiative. Yet at least 20 federal agencies and their sub-units have a clear stake in developing the STEM workforce and hire STEM graduates. These agencies are:

- Department of Agriculture (USDA)
- Department of Commerce (DOC), including heavily science and engineering-based units such as the National Institute of Standards and Technology (NIST) and National Oceanic and Atmospheric Administration (NOAA)
- Department of Defense (DOD), including the National Security Agency (NSA)
- Department of Education (ED)
- Department of Energy (DOE)
- Department of Health and Human Sciences (HHS), including National Institutes of Health (NIH)
- Department of Homeland Security (DHS)
- Department of Interior (DOI), including United States Geological Survey (USGS)
- Department of Labor (DOL)
- Department of State (DOS)
- Department of Transportation (DOT)
- Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)
- National Science Foundation (NSF)
- Smithsonian Institution (SI), including the Smithsonian Science Education Center

Each of these federal units will need dedicated funding to support the initiative, including by:

- Offering training and grants to help teachers and community scientists become effective K–12 research and project mentors.
- Providing monetary awards and increased recognition opportunities for students who participate in STEM competitions.
- Building an agency-wide mechanism to track outcomes of and build alumni networks for students who participate in initiative programs.
- Maintaining a central database to track metrics of initiative programs.
- Recruiting exceptional STEM students into the professional federal STEM pipeline.

We estimate that an average allocation of $25 million per year for 10 years per relevant federal unit would be sufficient to get the initiative off the ground. These funds alone are not enough to develop the STEM workforce to the level needed in the United States. However, consistent federal funding for K–12 research programming (and associated teacher training) would provide a solid foundation for addressing the shortfalls outlined at the beginning of this memo. To maximize the initiative's impact, additional funding should be allocated specifically for coordination and evaluation. Evaluations should be carried out every few years, and findings used to inform funding priorities and program structure as needed. Emphasis should be placed on allocating funds to expand access to high-quality STEM experiences for underserved and underrepresented students.

(3) Meaningful agency participation

The working group will identify existing federal programs that could be expanded to achieve the initiative's goal. The working group will also identify agencies that have relevant missions but currently lack relevant programs. See above.

(4) Partnership with non-federal organizations to provide programmatic content and complementary actions

The working group should partner with third-party organizations that already offer programs and resources (financial and in-kind) relevant to the initiative. These include but are not limited to:

- School-based programs.
- STEM nonprofit organizations that deliver curricula for teacher training.
- Scientific societies and trade associations.
- Post-secondary institutions such as community colleges, colleges, and universities.
- Private-sector companies.
- State and local governments.
- Philanthropic foundations organizations and individuals.

The next administration can use the power of the Federal Government to help such third-party organizations scale up and strengthen programs that have already proven effective, resulting in more teachers and scientists trained and more K–12 students able to participate in science and engineering research projects.

Precedents

The initiative outlined in this memo can and should build on multiple outstanding federal precedents. One example is the DOD's Defense STEM Education Consortium (DSEC).[19] The DSEC is a collaborative partnership among academia, industry, nonprofit organizations, and government that aims to broaden STEM literacy and develop a diverse and agile workforce with the technical excellence to defend our nation. (This program is in the process of a rigorous review but is considered by many people to be a model program. See FAQ). Many smaller federal programs provide teacher training in various STEM fields. The next administration should leverage and potentially refocus such existing programs to emphasize critical-thinking skills and research-based programs at the K–12 level.

Conclusion

The next administration should seize the opportunity to reinvigorate the STEM talent pool in the United States by creating the **Next Generation of STEM Talent Through K–12 Research Programming Initiative**. The initiative will motivate participation in STEM careers by making participation in hands-on STEM research and problem-solving opportunities a standard component of K–12 education. The COVID-19 pandemic has driven home just how critical a strong and diverse STEM workforce is to our nation's health and prosperity. Failure to replenish and grow our domestic STEM talent pool will lead to a decline in national innovation and economic progress. Only the Federal Government can address this need at the scale and pace needed.

Inclusivity is an indispensable aspect of this initiative. Building a robust STEM workforce in the United States requires us as a nation to draw on the talent of all Americans. The Next Generation of STEM Talent Through K–12 Research Programming Initiative will rediscover our country's "lost Einsteins": the underrepresented minorities, women and underserved students from rural communities who have the capacity to deliver transformative contributions to STEM if only they were provided opportunities to do so.

[19] U.S. Department of Defense (2015). DoDSTEM: Strategic Plan FY2016 – FY2020. https://dodstem.us/sites/default/files/DoD_STEM_Strategic_Plan_2015_1022.pdf.

Frequently Asked Questions

How does this idea complement existing actions already undertaken by the Federal government?

The current and previous administrations have taken multiple actions that serve as a foundation for achieving the goals of Ensuring the Next Generation of STEM Talent Through K-12 Research Programming. An outstanding example of a federal initiative that works is DOD STEM's Defense STEM Education Consortium (DSEC).[20] Aligned to the Federal STEM Education Strategic plan, the Defense Science, Technology, Engineering, and Mathematics Education Consortium (DSEC) is a collaborative partnership among academia, industry, non-for-profit organizations, and government that aims to broaden STEM literacy and develop a diverse and agile workforce with the technical excellence to defend our Nation. By addressing and prioritizing critical STEM challenges, DOD is investing in evidence-based approaches to inspire and develop the Nation's science and technology workforce.

This multi-year effort includes elements focused on STEM enrichment programs for students and educators, STEM workforce engagement, program evaluation, and public outreach. These efforts will allow DOD to improve access for students to pursue STEM careers and consider Defense laboratories as a place of employment. Through strategic investment in STEM education and outreach activities, the effort will provide students with more exposure to educational and career opportunities, as well as DOD research. The program includes scholarships, internships/apprenticeships, teacher training, and conferences. The program is in the process of being evaluated.[21]

Another example that could be adapted for K-12 are the existing programs funded by the National Science Foundation, which provides summer research experiences nationally and internationally to college students. Those programs involve partnerships with universities and non-for-profit scientific societies. Similar programs exist in many other federal agencies, but they are not coordinated nor specifically directed to building the STEM pipeline.

How much does the government spend on the area identified in the proposal?

This is unknown because the programs are not clearly identified by the government with line-item spending. One of the goals of the working group described in the main proposal would be to take an inventory of existing programs and identify which might be repurposed and which agencies could establish programs in keeping with the proposal.

[20] U.S. Department of Defense (2015). https://dodstem.us/sites/default/files/DoD_STEM_Strategic_Plan_2015_1022.pdf.
[21] Summary of DOD Workshop on STEM Evaluation, January 27, 2020. https://dodstem.us/sites/default/files/20200127_SummaryofDoDSTEMWorkshoponEvaluation_DistroA_Release.pdf.

Given that the current White House Office of Science and Technology Policy is understaffed, is there another agency in the Federal Government that coordinate?

Although OSTP is the obvious coordinating group, in the event it could not undertake a project of this size, the National Science Foundation in concert with the Department of Education would be an appropriate coordinator.

Since there are so many organizations in the private sector noted in the proposal doing similar types of programs, why should the Federal government step in?

While there are dozens if not hundreds of organizations doing similar types of programs, they are underfunded, uncoordinated, and under-evaluated. They are not uniformly distributed throughout the U.S., and their goals are also diffuse. In addition, existing programs do not all have as stated goals inclusivity; many tend to benefit white, affluent communities. Only the Federal government can create the umbrella to coordinate such programs, track them, and evaluate them.

If $500 million of funding is not available, what would a less ambitious version of this proposal look like?

The OSTP working group would need to prioritize the number of federal agencies and choose those that have the most at stake from this proposal—agencies that specifically need STEM workforce to carry out their mission. Narrowed in this way, the number of units might drop by 50%, from 20 to 10. The working group could also focus on those agencies that currently have robust programs in the same space and build on those. For example, more money might be given to the DSEC program.

In addition, funding should be continued and increased for the National Science Foundation to evaluate these programs from a rigorous viewpoint to determine whether they are succeeding. Continued funding would be dependent on the results of these evaluations.

About the Authors

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