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on
"Science, Technology, Engineering, and Mathematics (STEM) Engagement"

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Introduction

Chairman Serrano, Ranking Member Aderholt, and Members of the subcommittee, my name is Karen Marrongelle and I am the Assistant Director for Education and Human Resources at the National Science Foundation (NSF). It is a privilege to be here with you today to discuss science, technology, engineering, and mathematics (STEM) education investments at NSF.

Established by the National Science Foundation Act of 1950 (P.L. 81-507), NSF is an independent Federal agency whose mission is "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF is unique in carrying out its mission by supporting fundamental research across all fields of STEM, and all levels of STEM education. NSF is committed to the development of a future-focused science and engineering workforce that draws on the talents of all Americans. NSF accounts for approximately 25 percent of the total Federal budget for basic research conducted at U.S. colleges and universities and has been vital to many discoveries that impact our daily lives and drive the economy.

At NSF, our education activities are integrated with and integral to science and engineering research and innovation. We recognize that combining the best that we know from research about learning and cognition with exciting opportunities to learn STEM is a winning combination for helping to effectively inspire and prepare the next generation STEM workforce. Beyond the STEM-specific workforce, we know that STEM literacy is critical to having a productive and effective future citizenry.

Overview

NSF's education and STEM workforce investments are primarily housed in the Directorate for Education and Human Resources (EHR). The directorate's role in accomplishing NSF's mission is to advance excellence in U.S. STEM education at all levels and in all settings to support the development of a diverse and well-prepared workforce of scientists, technicians, engineers, mathematicians and educators and a well-informed citizenry that have access to the ideas and tools of science and engineering. To accomplish this, EHR invests in the development of people and knowledge.

Unique in the federal context, NSF EHR programs fund the discoveries—the crucial foundational research and the design and implementation studies—that underpin STEM education initiatives. STEM education research asks and answers important questions such as: *Why are fractions so difficult to learn? What are the most effective ways to teach the concept of force? How do we prepare teachers to teach engineering design to students from diverse backgrounds?*

Just as NSF's research directorates are dedicated to funding basic research that accelerates progress in science and engineering, EHR supports early-stage, exploratory research that enables improvements in STEM teaching, learning, and assessment. In addition to tackling persistent STEM educational questions, EHR funds research that investigates the future of educational places and spaces. Each decade brings new challenges, new learnings, and new opportunities to enhance STEM learning—and as scientists and engineers make new discoveries, education must adapt to the new skills and knowledge necessary for our nation to stay on the cutting-edge of scientific advances. For example, classrooms of the future may engage students with adaptive robots that are teachable, and even social. NSF currently funds a project at New York University to explore how robots can help students learn geometry and computational thinking. In this technological innovation, middle school students are empowered to systematically teach a robot about geometry while the robot provides expressive feedback and social support. In the process, students refine their own understanding of STEM topics while enhancing self-reflection and intrinsic motivation during problem-solving.

Knowledge arising from EHR's research portfolio informs EHR's human capital initiatives and a suite of NSF-wide investments in preK-12, undergraduate and graduate STEM education, and broadening participation. Importantly, results, data, and innovations arising from EHR-supported research are available to catalyze discoveries and inform investments at scale made by other agencies, organizations, and the private sector. For instance, in the 1980's, EHR funded pioneering work at Carnegie Mellon University to develop computer-based math tutors, with a focus on helping high school students learn algebra. One version of this tutoring system was tested in a trial involving 146 schools, in seven states, with more than 18,000 students. Carnegie Learning is now a private company providing math tutoring products used by 500,000 students per year in school districts in Wisconsin, Minnesota, Illinois, Florida, Kentucky, Pennsylvania, and West Virginia, among other states.

Collectively, EHR's research investments provide the knowledge capital that underpins a broad spectrum of STEM education initiatives—at NSF, federally, in schools and institutions of higher education, online, and in libraries, museums, and other learning contexts across the country.

Charting a Course for Success: America's Strategy for STEM Education

The National Science and Technology Council's (NSTC) Committee on STEM Education (CoSTEM) was established pursuant to the requirements of the America COMPETES Reauthorization Act of 2010 (42 U.S.C. 6621). The Committee reviews STEM education programs, investments, and activities in Federal agencies to ensure that they are effective; coordinates, with the Office of Management and Budget, STEM education programs, investments, and activities throughout the Federal agencies; and develops and implements through the participating agencies a STEM education strategic plan, to be updated every five years. NSF's Director, Dr. France Córdova, co-chairs CoSTEM with NASA Administrator Jim Bridenstine, and Dr. Kelvin Droegemeier, the Director of the Office of Science and Technology Policy (OSTP).

I currently co-chair the CoSTEM Subcommittee on Federal Coordination in STEM Education (FC-STEM) with Mike Kincaid, the Associate Administrator for STEM Engagement at NASA, and Cindy Hasselbring, the Assistant Director for STEM Education at OSTP. FC-STEM advises and assists CoSTEM and serves as a forum to facilitate the formulation and implementation of the five-year STEM strategic plan.

The most recent five-year strategic plan for STEM education, *Charting a Course for Success: America's Strategy for STEM Education*, is based on a vision for a future where all Americans will have lifelong access to high-quality STEM education and the United States will be the global leader in STEM literacy, innovation, and employment. The plan accordingly strengthens the Federal commitment to equity and diversity, to evidence-based practice, and to engagement with the national STEM community through a nationwide collaboration with learners, families, educators, communities, and employers.

The strategic plan is a product of extensive input from stakeholders representing the broad STEM education ecosystem—Federal, State, Territorial, Tribal, and local; public and private; formal and informal—including the recently chartered STEM Education Advisory Panel. The strategy realigns the focus of Federal agency STEM education programs, investments, and activities with the priorities and needs of both the Administration and the national STEM community.

NSF's research and human capital investments are consistent with the three aspirational goals highlighted in *Charting a Course for Success: America's Strategy for STEM Education:*[1] (1**) build strong foundations for STEM literacy**; (2) **increase diversity, equity, and inclusion in STEM**; and (3) **prepare the STEM workforce for the future**. NSF programs collectively educate, train, and support discoverers; engage citizen scientists; and foster a well-informed, STEM-literate citizenry to ensure that the country has an exceptionally skilled and diverse STEM workforce that meets today's needs and is prepared to meet the needs of the future.

[1] https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf

Building Strong Foundations for STEM Literacy

STEM learning begins in early childhood and continues throughout life, both in and out of school. The EHR portfolio includes the design, implementation, and study of learning environments, models, and digital platforms intended to enable STEM learning for all students— particularly those from groups that have been underrepresented in STEM—through both formal and informal activities across the STEM ecosystem. EHR supports research with immediate applicability as well as projects that envision STEM education as it could be well into the future. Results are expected to catalyze new approaches to STEM learning, teaching, and assessment; build knowledge about how to develop preK-12 students' STEM knowledge and skills; and provide multiple pathways and resources in a variety of learning environments to study the learning process itself, that can serve as models for use within the nation's formal preK-12 STEM education and beyond.

Learning occurs across the lifespan and in places and spaces beyond schools or the school day. Developments in technology continue to influence the ways and means for learning, including 24/7 access to information, tools for learning collaboratively, personalization of learning, and authentic/deeper contributions to scientific processes and studies. The social context of science is also changing. This social context has contributed to a changing role of science in people's lives, which has resulted in the shifting dynamics of learning (e.g., do-it-yourself movement, public participation in scientific research, access to low cost, high quality sensors, and other tools to conduct one's own investigations), and interest in the interconnections and interdisciplinary of science with other disciplines. In addition, advances in brain research, cognition, and other domains have stimulated interest in expanding notions of how early in life the learning of science, technology, engineering, and mathematics can occur. Such advances, however, are situated within the reality that there is unequal distribution of and access to quality STEM learning experiences for individuals, family, and communities.

Almost any environment can support informal STEM learning—a home, a museum, a library, a street, or a virtual or augmented reality game. Information networks, mobile media, and social networks have transformed educational possibilities and created opportunities for seamless learning environments. Informal learning environments are, in principle, accessible to all learners, and evidence suggests they have particular potential for supporting learners from underrepresented groups (National Research Council, 2009[2]). These settings offer learners direct access to compelling phenomena in the natural and designed world, and powerful representations of those phenomena. Ubiquity, digital networks, and lack of formal accreditation procedures mean that anyone with appropriate expertise can facilitate STEM learning in the informal world.

[2] National Research Council (2009). *Learning Science in Informal Environments: People, Places, and Pursuits* Washington, D. C.: The National Academies Press http://www.nap.edu/openbook.php?record_id=12190.

Increasing Diversity, Equity, and Inclusion in STEM

In order for the United States to continue to be the leader in science and engineering research and innovation, we must grow a vibrant and diverse U.S. STEM workforce by supporting the inclusion in, and broadening participation of, individuals who have not had opportunities to thrive in STEM. A key underpinning of EHR's portfolio is to broaden participation in STEM. This includes the development of, and research on, effective mechanisms and models for broadening participation, institutional transformation through institutional policies and practices, capacity building for STEM and STEM education research at minority-serving institutions, and faculty and student development.

One of the boldest EHR-led initiatives of recent years is NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science). NSF INCLUDES is a comprehensive national initiative designed to enhance U.S. leadership in STEM discoveries and innovations by focusing on broadening participation in these fields at scale. The vision of NSF INCLUDES is to catalyze the STEM enterprise to collaboratively work for inclusive change, which will result in a STEM workforce that reflects the population of the Nation.

NSF INCLUDES is already on its way to making substantial advances toward a diverse, innovative, and well-prepared STEM workforce to support our Nation's economy and continued U.S. leadership in the global STEM enterprise. With over 20,000 participants and close to 900 partners, the NSF INCLUDES National Network is delivering on its promise to scale-up proven practices through partnerships to foster new and improved STEM career pathways, policies, opportunities to learn, and practices for equity and inclusion.

According to a 2019 National Academies of Sciences report entitled *Minority Serving Institutions: American's Underutilized Resource for Strengthening the STEM Workforce*[3], "research suggests that the cultural diversity of a nation's workforce is a key factor in its ability to innovate and compete in a global economy." As well, the nation will need many more STEM professionals than are predicted to be produced in the coming decade. The nation's minority-serving institutions (MSIs) are in a unique position to educate our future diverse and competitive workforce.

NSF supports research and development at MSIs including Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs) and most recently, Hispanic-serving institutions (HSIs). The program to serve HSIs was established in response to legislation written to enhance the quality of undergraduate STEM education at HSIs and to increase the retention and graduation rates of students pursuing associate's or baccalaureate degrees in STEM. In addition, the HSI program is intended to build the capacity for STEM research and education at HSIs that typically do not receive high levels of NSF funding.

[3] National Academies of Sciences, Engineering, and Medicine. 2019. *Minority Serving Institutions: America's Underutilized Resource for Strengthening the STEM Workforce*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25257.

While the first HSI projects are still getting under way, the program's exciting potential can easily be seen from the project descriptions. For example, Principal Investigator Eva Fernandez at CUNY Queens College plans to increase undergraduate student interest and retention in STEM by enriching STEM courses with project-based learning activities that introduce students to making and design thinking. Further, the project is intended to build the capacity for faculty in STEM research and education through a partnership between Queens College (an HSI) and the New York Hall of Science (a science museum). The project's impact on undergraduate students will be investigated using data linked to STEM achievement and persistence (from institutional records) and measures of motivation (from surveys). The project will also host a public forum at which students can present or demonstrate their projects and will also share findings through a public web site.

To further expand the impact of the HSI program, an HSI STEM Resource Hub has been awarded at New Mexico State University, in collaboration with Doña Ana Community College and California State University-Northridge. The HSI STEM Resource Hub web site shares resources on issues important to HSIs and hosts a STEM Network that fosters collaboration. The Hub has also sponsored grantsmanship workshops for institutions new to NSF. A few days ago, the HSI HUB partnered with the NSF-funded West Big Data Innovation Hub to host a two-day workshop for HSI faculty on data science, and how to incorporate data science themes into undergraduate STEM courses.

While the HSI program is only a few years underway, EHR has demonstrated the impact of sustained and focused funding to broaden participation in STEM. For instance, the 18-year old Tribal Colleges and Universities Program (TCUP) has supported an increase in the number of STEM degree programs at tribal colleges and helped to foster the evolution of several tribal colleges from two-year to four-year institutions. For example, Navajo Technical College (now Navajo Technical University) developed an engineering bachelor's degree program that was fully accredited by the Accreditation Board for Engineering and Technology (ABET) in August 2018. Navajo Technical University was the first Tribal College to earn ABET accreditation. As of August 2019, fourteen students, all enrolled tribal members, have graduated from the program and gone on to graduate school or into high-paying jobs in industry. Some have even started their own companies.

NSF established the Historically Black Colleges and Universities Undergraduate Program (HBCU-UP) in 2000. HBCU-UP provides awards to develop, implement, and study innovative models and approaches for making dramatic improvements in the preparation and success of underrepresented minority students so that they may participate in STEM graduate programs and the workforce—and the program has had a strong impact on HBCUs. A third-party evaluation found that over 70 percent of HBCU-UP graduates pursued additional coursework after completing their undergraduate degrees, with almost 60 percent eventually enrolling in a graduate degree program. An example of impact through a HBCU-UP project is the development of STEM degree programs in Mathematics and Biology at Harris-Stowe University following an HBCU-UP award in 2008.

Preparing the STEM Workforce for the Future

From early childhood to adulthood, NSF supports initiatives that build the STEM-capable U.S. workforce of the future and ensure Americans are prepared to meet evolving workforce demands. NSF partners with academia, government, and industry to develop and leverage education and training opportunities, which result in increased levels of STEM employment and job creation.

The five-year STEM strategic plan reflects new and renewed areas of emphasis, such as a focus on the development of America's skilled technical workforce. In September 2019, the National Science Board (NSB) released a report titled, *The Skilled Technical Workforce: Crafting America's Science & Engineering Enterprise*,[4] which identifies opportunities and challenges facing students, incumbent workers, businesses, educators, and others involved with the United States science and engineering enterprise. NSF will continue to build on the recommendations of the strategic plan, as well as initiatives such as the NSB skilled technical workforce task force report, as the agency works to ensure that all Americans have lifelong access to high-quality STEM education to ensure the United States will be the global leader in STEM literacy, innovation, and employment.

Educating a highly skilled technical workforce is the mission of NSF's Advanced Technological Education (ATE) program, a program based primarily in community colleges that focuses on the education of technicians for the high-technology fields that drive our nation's economy. The program, which has been advancing technological education for over twenty-five years, involves partnerships between academic institutions and industry to promote improvement in the education of science and engineering technicians at the undergraduate and secondary institution school levels. The ATE program also supports centers to develop an integrated approach to technician training that define and disseminate the critical knowledge and skills required to support the advanced technology industries in the U.S. Topic areas for centers include advanced manufacturing technologies, agricultural technologies, biotechnology, energy technologies, environmental technologies, engineering technologies, security technologies, and micro- and nano-technologies.

Technology and the STEM workplace are changing rapidly, presenting new opportunities and challenges for training, skilling, and re-skilling of the STEM workforce. This year, NSF partnered with The Boeing Company to support a new initiative to accelerate training in critical skills areas for the nation's engineering and advanced manufacturing workforce. The *Production Engineering Education and Research* (PEER) initiative supports foundational research arising from the design, development, and deployment of creative online curricula that provide learners at various levels with skills in model-based systems engineering, software engineering, mechatronics, data science, and artificial intelligence. Additionally, projects investigate the future of production engineering education—the future of work—research that will transform our workplaces, empower our workforce, and provide tremendous new sources of innovation for our nation.

[4] https://www.nsf.gov/nsb/publications/2019/nsb201923.pdf

Conclusion

The discoveries and innovations funded by NSF have a long record of improving lives and meeting national needs. With the support of this Committee and the Congress, NSF will continue to invest in the fundamental research and the talented people – the discoveries and the discoverers – who improve our daily lives and transform our future.

Thank you for the opportunity to testify today and for your continued support of NSF. I will be pleased to answer any questions you may have.

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Dr. Karen Marrongelle is the Assistant Director of the National Science Foundation (NSF) for Education and Human Resources (EHR). She leads the EHR directorate in supporting research that enhances learning and teaching to achieve excellence in U.S. science, technology, engineering and mathematics (STEM) education.

Prior to joining NSF, Marrongelle was dean of the College of Liberal Arts and Sciences at Portland State University and Professor of Mathematics and Statistics, where she oversaw 24 departments and programs across the humanities, social sciences and natural sciences.

In addition to her work as dean, Marrongelle, has served as a faculty member in the Department of Mathematics and Statistics at Portland State University since 2001. Prior to her appointment as dean, she held positions as the Vice Chancellor for Academic Strategies and Assistant Vice Chancellor for Academic Standards and Collaboration with the Oregon University System.

From 2007-2009, Marrongelle served on a rotation as a program officer at NSF and led numerous grants, collaborating with researchers nationally and internationally to improve undergraduate mathematics education and K-12 mathematics professional development.

Marrongelle has a bachelor's degree in mathematics and philosophy from Albright College, a master's degree in mathematics from Lehigh University and a doctorate in mathematics education from the University of New Hampshire.