

Testimony of

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National Academies of Sciences, Engineering, and Medicine

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On

ACHIEVING THE PROMISE OF A DIVERSE STEM WORKFORCE

May 9, 2019

Chairwoman Johnson, Ranking Member Lucas, and Members of the Committee, thank you for inviting me to testify today on the critical issue of achieving a truly diverse STEMM workforce (Science, Technology, Engineering, Mathematics, and Medicine).

I am an individual who has been exposed to both the most advanced technologies and bountiful economic resources and the woeful pittance of human compassion.

And, I have lived with people having meager resources who persevered in conditions that would try all of us mentally, relying on technologies that have served outstandingly for a thousand years, yet who would share all they have with a stranger.

Over the course of my training and career I have attended and taught in schools, programs and universities that may have been classified at different times as the best and worst in our nation and the world – Cambodian refugee camps, Chicago Public

¹ The **100 Year Starship (100YSS)** is a private non-profit, non-governmental global initiative seed-funded via a competitive joint U.S. Defense Advanced Research Projects Agency (DARPA) and National Aeronautics and Space Administration (NASA) grant. The objective is to ensure that the capabilities for human interstellar flight exist within the next 100 years while triggering and applying the radical research and innovations required to meet such a challenge here on Earth every step of the way.

Schools and Los Angeles Unified School District, Stanford, Cornell, Dartmouth, Freetown, Sierra Leone. As a former astronaut, Area Peace Corps Medical Officer, physician, chemical engineer, environmental studies professor, business owner and educator, I consider it part of my responsibility to help facilitate the promise of STEMM disciplines to build a beneficial future.

I come to this issue from multiple vantage points: I am the Principal for the 100 Year Starship initiative to ensure the capabilities for human interstellar flight in 100 years; a member of the board of the National Board of Professional Teaching Standards; Bayer's Science Literacy Ambassador; founder of The Earth We Share international science camp; and, I am privileged to currently serve as chair of the National Academies of Sciences, Engineering, and Medicine's Committee on the Underrepresentation of Women in Science, Technology, Engineering, Mathematics, and Medicine.²

It is through the range of my experiences in STEMM fields and in life that I offer my testimony today.

STEMM Diversity: A Necessity, Not a Nicety

Today, we are at a critical point in world and US history— we are struggling to meet the demand, the imperative to improve human quality of life while not overburdening this planet. The best paths forward are not clear. Whether one expresses this drive for enhanced quality of life in terms of economics, life expectancy, or fast cars and fast food, it is at the center of all our activities and ambitions. And the “solutions” born from the output of STEMM fields are leading the way, cutting a wide swath in our daily lives, through our consumption and production of energy, toys, health care, food, transportation, news, defense, entertainment—you name it.

The way being slashed is not necessarily a good path. Yet we are defining and building that path with less than a third of the intellectual capacity, experience, ambitions, vision and perspectives available to us.

² More than 150 years ago, the National Academy of Sciences was created through a congressional charter signed by Abraham Lincoln to serve as an independent, authoritative body outside the government that could advise the nation on matters pertaining to science and technology. Under that original charter, the National Academy of Engineering (NAE) was founded in 1964 and the National Academy of Medicine (NAM, formerly the Institute of Medicine, IOM) in 1970. Every year, approximately 6,000 Academies members and volunteers serve pro bono on our consensus study committees or convening activities. Our consensus study process is considered the gold standard of independent, nonpartisan, evidence-based advice. We do not advocate for specific policy positions. Rather, we enlist the best available expertise across disciplines to examine the evidence, reach consensus, and identify a path forward on some of society's most pressing challenges.

Women and most US ethnic and racial minorities, who make up two-thirds of our population, are underrepresented in all levels of the STEM workforce. The ‘Findings’ of H.R. 2653, the “STEM Opportunities Act of 2017,” provide an excellent overview of the current status of women and underrepresented minorities in STEMM. While improving, the numbers remain poor and progress is too slow.

The importance of diversity in STEMM for me is not just about improving US competitiveness by having more folks who can ‘fill seats’ to ‘create’ more things, technology or ‘stuff’.

The scientists, engineers and those who fund and support them steer the impact – rewards and benefits—accruing from STEMM fields. The scientists, engineers and those who fund and support them get to choose:

- Topics and phenomena to be researched;
- Methodologies used in studies;
- Data sets to be analyzed, shelved for later, disregarded or thrown out as irrelevant or flawed;
- Problems to be solved and the priority in which the problems are addressed;
- Solutions and technologies targeted for development and the populations for which they are relevant; as well as
- The means, methods and standards used to assess the effectiveness of therapies, solutions, technologies and implementations.

Regardless if one assumes that a scientist or engineer will arrive at the same answer or interpretation of a natural phenomenon once a topic is chosen for analysis, clearly the decision to use a certain combination of minerals to propel a bullet or create a beautiful fireworks display is a choice heavily dependent upon personal experiences, values, ambitions and world view.

“The future never just happened; it was created”

Will and Ariel Durant.

The unprecedented advancements of physical, digital, and biological technologies are poised to fundamentally alter the way we live, what we value, and how we interact with each other. We have an opportunity and the responsibility to exercise foresight and mitigate unintended consequences. The shifts in technology and economic landscapes

will generate new jobs and occupations, while displacing others. If the inequities that exist today persist, they will likely only worsen during this shift. However, if we conscientiously address the inequities in STEMM education and careers, we may harness the power of what has been called this Fourth Industrial Revolution to create a better world for all.

To do so requires that the people guiding, developing, and implementing the technological underpinnings of this revolution reflect the diverse makeup of our citizenry. Right now, it does not. Today, the STEMM workforce that is researching, developing, and designing the powerful digital technologies that influence almost every aspect of our lives is dominated by a single demographic group. In 2014, Google released demographic data on its employees: 83% of employees were male and only 3% and 2% of those employees were Hispanic or African American, respectively. I commend Google for openly sharing these data because it is only through seriously confronting a problem that we can work to understand the problem and address it.

There are real opportunity costs attendant to the homogeneity of our STEMM workforce. Research highlights that greater diversity can yield many benefits in business and academia, including, but not limited to:

- More innovation
- Improved financial performance
- More effective and efficient problem solving
- Reduced conflict in the workplace
- Increased creativity
- Lower employment turnover
- Higher publication rates with greater impact.

Surely this is all very logical and unsurprising. Does it not make sense that when the thinkers, developers, and implementers at the table better reflect the makeup of the population, the output will be more robust, innovative and effective?

Supporting a diverse STEMM workforce reduces the likelihood of developing products and services that are skewed to advantage only a single group. Unfortunately, we have many examples of technological innovations with crucial design faults because they were developed by a homogeneous group. For instance, issues related to car crash-test dummies are designed based on the “average” male, such that when a woman is involved in a car crash, she is 47% more likely to be seriously injured and 17% more likely to die, even when controlling for factors such as height, weight, seatbelt usage, and crash intensity. Another example is offered by a recent report that found that Black

individuals were the most likely to be scrutinized by facial recognition software. It also suggested that software was most likely to be incorrect when used on Black individuals-- a finding corroborated by research by the FBI. Issues like this are born out of a lack of gender and racial diversity in the technology sector.

The relative homogeneity of the leadership of the STEMM workforce and industries has far reaching implications for the nation's broader research and innovation agenda. Many issues of national importance do not receive adequate attention because not all voices are given equal priority; certain subsets of the population drive the focus and priority of our STEMM. For example, why is it that maternal mortality is higher in the United States than in any other developed country?

Frequently when the STEMM workforce equity and diversity is contemplated, the focus is on the academy and jobs requiring four year or advanced degrees. The reality is that the majority of STEMM jobs are for skilled technicians requiring high school, community college or two year degree programs. And these jobs pay substantially more than other jobs with the same years of education. Yet women and underrepresented minorities are frequently unaware of and left out of pathways to these careers.

National Academies Study on Addressing the Underrepresentation of Women in STEMM

I am pleased to be the Chair of the National Academies study on the topic of women and STEMM, which will offer a detailed overview of the research and a set of actionable recommendations on how to improve the education, recruitment, retention, and advancement of women in STEMM. My hope is that the study report will help to guide action on the part of a diverse array of stakeholders--educational institutions, policymakers, funders, media and employers-- that we so desperately need. With the support of the National Institutes of Health, the National Science Foundation, and L'Oréal USA corporation, the National Academies assembled an expert committee comprised of distinguished scientists, engineers, and medical professionals from industry and academia and leading researchers on women's underrepresentation in STEMM disciplines and the intersectionality of race and gender in STEMM. Our task as a committee focuses on understanding the basis for effective solutions, the barriers and opportunities for the scaling and adoption of such solutions, and with particular exploration on the intersectional experiences of women of color. When the report is released in November 2019, I will arrange for every member of this Committee to receive a hard copy, and I would welcome an opportunity to return before you to brief

you on the report's findings and recommendation. For now, let me give you some of the background that provides the context for our approach to this study.

Women Remain Underrepresented in STEMM

The number of women in science is growing, yet women—especially women of color-- remain underrepresented in STEMM relative to their representation in the U.S. population. This representation varies by discipline and field. For example, though women are at parity at the undergraduate and graduate levels in the life sciences, women make up fewer than 25% of bachelor's and doctoral degree recipients in engineering and computer science. The numbers are even lower for women of color, who in 2014 earned fewer than 12% of STEM degrees.

Even in fields in which women are at parity—such as in biology and certain medical specialties--women are underrepresented among the senior ranks in these fields. For example, women doctors comprise 51% of medical instructors, but their representation steadily declines from the Assistant Professor level (43%) to Associate Professors level (33%) to Full Professor level (20%) (Association of American Medical Colleges, 2016).

The underrepresentation of women in STEMM is driven by a range of well-researched biases and structural inequities that we will be reporting on in great detail in the forthcoming National Academies report. But from what the committee has heard thus far in its public meetings, and from our consultation of previously published National Academies reports on this topic³⁴⁵⁶, it is clear that women in STEMM experience the following barriers:

³ National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2007. *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/11741>.

⁴ National Research Council. 2013. *Seeking Solutions: Maximizing American Talent by Advancing Women of Color in Academia: Summary of a Conference*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/18556>.

⁵ National Research Council. 2006. *To Recruit and Advance: Women Students and Faculty in Science and Engineering*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/11624>.

⁶ National Research Council. 2001. *From Scarcity to Visibility: Gender Differences in the Careers of Doctoral Scientists and Engineers*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/5363>

- Bias in recruitment
- Unequal allocation of resources and pay
- Less access to mentoring
- Higher teaching loads
- Bias in teaching evaluations
- Bias in authorship credit
- Bias in peer review
- Fewer speaking invitations
- Higher service expectations
- Uncivil treatment
- Assault

For women of color, the experiences of gender discrimination are compounded by racial and ethnic discrimination. Such experiences contribute to a “double bind” in which women of color experience increased bias at key career junctures and often hostile environments.

Despite the many barriers that hold women back, reduce their productivity and success, or force them to leave STEMM, we should not lose sight of the fact that many women persist in these fields, making significant contributions to STEMM and to society. Sadly, too often these contributions are omitted from history books and are not valued in the same way as the contributions of men. For instance, research shows that women are less likely to be called “geniuses” or “brilliant” than men and that their contributions are often attributed to hard work and luck rather than to innate talent. Nevertheless, if we reflect on the subset of women whose contributions our society does celebrate, we are reminded of how much would be lost without their efforts.

Where would we be without Rosalind Franklin and her discovery of the structure of DNA; or Katherine Johnson’s calculation of lunar trajectories; or Frances Kelsey’s fight to keep thalidomide off the drug market in the U.S.; or Ada Lovelace’s foundational work in computer science; and so many other powerful and significant contributions from women in STEMM? We are lucky that many pioneering women have persisted, yet I urge you to consider: how many outstanding contributions to the fields of science, technology, engineering, mathematics, and medicine have we lost by pushing women out of these fields? What is the world going to be like in 10, 20, 100 years if we continue to exclude more than 50% of the world’s population from full participation in helping to identify and solve the global challenges of our era?

We are still in the process of conducting the National Academies study, so today I offer comments based on my knowledge and experiences and from what I am learning through the information gathering activities of the National Academies study.

If you wait for tomorrow, tomorrow comes. If you don't wait for tomorrow, tomorrow comes.

African Proverb

I am pleased that the hearing today serves to raise awareness and understanding of the issue of women's and minorities' underrepresentation in science, technology, engineering, mathematics, and medicine (STEMM). However, I am disappointed that we are still having this conversation despite the fact that the many barriers facing these groups in science are very well researched and well understood, as are the strategies for improving the recruitment, retention, and advancement. And the strategies improve the achievement of all in STEMM.

Progress is stymied by ingrained bias—implicit and explicit, tolerance of the status quo, lack of accountability, markedly uneven distribution and access to educational and investment resources, gatekeepers blissfully unaware of the how the culture of the STEMM disciplines actually hinders the beneficial contributions it can make to society and lack of commitment by leadership. When these challenges are addressed, then practices are not just promising, they deliver remarkable results. Examples of some such practices and strategies follow.

Excellent Education Must Be Universal.

Education is fundamental to STEMM success. Its starts in childhood, first at home and then in school. Schools, curriculum and teachers, K-12, are key. Requirements: hands-on education, excellent teachers, national standards and access to quality education for every child regardless of their parent's economic wherewithal, educational attainment, knowledge or zip code.

Teachers

To quote Dr. Peggy Brookins, *"What child doesn't deserve an excellent teacher?"*

Accompanying me today is Dr. Brookins, the CEO of the National Board of Professional Teaching Standards and a Certified Teacher. The National Board Certification represents the gold standard in teaching. Teachers who achieve this distinction have earned the profession's highest mark of achievement through a rigorous, performance-

based, peer-review process, demonstrating their proven impact on student learning and achievement.

More than 122,000 teachers have earned Board Certification, including 61,039 in STEM-related fields. Board Certification is available in 25 subject and grade levels including math, science, and career and technical education. More than a decade of research from across the country confirms that students taught by National Board Certified Teachers (NBCTs) learn more than students taught by other teachers. In STEM fields the impact on student achievement is clear:

- According to the Harvard Strategic Data Project (2012), NBCTs produce an estimated 2 months of additional learning in Math for students in an academic year.
- For middle school mathematics, the effectiveness of NBCTs relative to non-NBCTs is about 50-75% of the return to the first five years of experience, according to Cowan & Goldhaber (2015).
- Goldhaber and Anthony (2007) further find that the positive impact of NBCTs is even greater for minority and low-income students
- Students of NBCTs demonstrate evidence of deeper learning nearly three times more frequently than their peers. Research by John Hattie and others finds student work samples that reflect deeper learning, in 74% of the classrooms of NBCTs compared to the 29% of the classrooms of non-NBCTs. (Smith, Baker, Hattie, & Bond, 2008).
- Research shows that policies that award financial incentives to National Board Certified Teachers in high need schools improve retention of these accomplished teachers at the schools that need them most. This is particularly relevant given the shortage of accomplished teachers in STEM fields. (Cowan and Goldhaber, 2018).
- There is evidence that on the whole NBCTs are retained longer, the South Carolina Center for Educator Recruitment, Retention, and Advancement found that NBCTs are retained at 4 times the rate of non-NBCTs, with a 1.9% turnover rate for NBCTs compared to 7.7% for other teachers (CERRA, 2017).

Effective Curriculum

For more than 50 years, Bayer has demonstrated a commitment to science literacy and has worked tirelessly to advocate for STEM (science, technology, engineering and math) education and careers. In 1995, Bayer formalized this commitment with creation of its national, Presidential-award-winning Making Science Make Sense® (MSMS) initiative. MSMS focuses on:

- Advocating for scientific literacy
- Promoting and providing hands-on, inquiry-based learning (learning by doing)
- Creating awareness about and access to careers in STEM
- Creating awareness of the importance of diversity in STEM

Bayer was an early trailblazer in science education reform, starting two organizations with seed money - ASSET STEM Education (Pittsburgh) and BioTech Partners (Berkeley) - both of which have sustained as independent education nonprofits since the early 90s.

ASSET STEM Education™ is a national education improvement nonprofit that provides educators, schools and educational organizations (serving Pre-K through career) with...

- proven professional development
- evidence-based, hands-on learning materials
- customized consulting services

Using a "teachers teaching teachers" model, ASSET supports systemic school wide and districtwide changes. ASSET's programs: (a) relate to standards-based curricula; (b) incorporate research-based classroom practices; (c) allow teachers to experience firsthand what students will experience; (d) model inquiry-based teaching and learning; (e) embed reflection/meaning making; and (f) support the development of educators into leaders.

Students learn by doing. For example they learn about insect metamorphosis by growing caterpillars and monitoring their growth into butterflies. Basics of electricity are learned through wiring flashlights and models of homes.

Students in the ASSET program improved science scores but saw even greater improvement in reading and math. ASSET serves more than 2,500 educators impacting more than 150,000 students annually. The organization is part of 100Kin10, Change the Equation and STEMx—national coalitions for developing excellent STEM teachers, sharing best practices and scaling effective practices in science, technology, engineering and math (STEM) education.

BioTech Partners

Established in 1993 as part of a development agreement between Bayer and the City of Berkeley, Biotech Partners is an now independent non-profit organization, collaboration of biotech companies in the Bay Area and that focuses on helping students underrepresented in the field of biotechnology attain personal, academic, and

professional development experiences through in-classroom instruction and paid internships within the biotech and health industries. BioTech partners works with ‘at risk’ students entering high school. These are students who ordinarily would be expected not to finish high school or graduate. Yet, Biotech students Partners has a graduation rate of 99% and most graduates are able to be certified as skilled biotechnicians immediately.

Informal Experiential Programs

Named after my mother, who was a school teacher in the Chicago Public Schools for over 25 years, the Dorothy Jemison Foundation for Excellence engages girls and boys in science through programs like our four-week residential summer camps specifically designed for middle school and secondary school students, ages 12-16. These camps successfully increase our students’ science literacy, their problem-solving skills, their knowledge of the impact of science and technology on society, and their understanding of societal and environmental impact on science endeavors. Their learning occurs in an encouraging and exciting atmosphere where they are supported, while being challenged to reach their greatest potential. Interestingly, our The Earth We Share™ international science camp receives far more applications from girls than boys! Founded in 1994, teachers and their training in with experiential, open-ended curriculum are at the center of TEWS™.

TEWS: Space Race™ was a non-residential program developed with the Los Angeles Unified School District and the Compton School District training over 200 middle school teachers and three thousand students.

Research Reveals How Institutions Can Work to Improve the Recruitment, Retention, and Advancement of Women in STEMM

The persistent underrepresentation of women in STEMM is discouraging, but even more discouraging is the fact that this underrepresentation persists despite the existence of a body of research and practice on effective strategies and policies for improving the representation and experiences of women in STEMM fields. Some institutions have adopted such practices and seen marked improvements in women’s representation. For example, at Carnegie Mellon, directed efforts to recruit women in computer science resulted in an increase of representation from 7% to 42% over 15 years from 1995-2000 (Fisher et al., 1997). At University of Michigan, sustained institutional support for a range of interventions developed through the NSF ADVANCE program led to an increase in the percentage of women hired (as a proportion of all new faculty

hired) from 13% in 2003 to 31% in 2016⁷. While these examples are encouraging, unfortunately, such success stories are relatively rare.

Gatekeepers, Accountability and Organizational Culture

The barriers faced by women and underrepresented minorities are insidious and pervasive compromising careers, contributions and economics of individuals and institutions. Often the culture of an institution, no matter how prestigious and accomplished can produce surprisingly dismal results. Regardless of the level of an individual's achievement and national visibility, gatekeepers often are not held accountable for acting, unconsciously or consciously upon ingrained biases. With full knowledge, those in positions of authority may decline to provide appropriate equipment and supplies or blatantly change standards after women and minorities have met criteria that should lead to promotion and leadership positions. Individuals are told they need to make the gatekeeper "feel more comfortable" with them and their capabilities.

This even happens in great organizations--including institutions that seem to have made exceptional progress. A case in point is NASA and the astronaut corps. We are all familiar with the seemingly inexplicable unavailability of medium sized EVA suits (spacesuits) on the International Space Station, which has delayed the deployment of two women simultaneously on a spacewalk. There was a conscious decision to limit the size of spacesuits over a decade ago, which disproportionately impacted women's opportunities to do space walks. And it pains me to highlight it here and to call out the consequences of the capricious intersection of race and gender.

First, I am honored to have had the opportunity to be the first woman of color in the world to have flown into space as a NASA astronaut. Dr. Peggy Whitson, a woman, has the most time of any US astronaut in space.

However, running a different set of numbers is instructive. There have been six African American women accepted into the NASA astronaut program out of over 338 astronauts total. As of today, May 9, 2019, one woman is still an ASCAN (in astronaut candidate training with her class that entered the corps in 2017). The remaining five African American women all completed their ASCAN training and passed all the qualifications for spaceflight; yet only three have flown. Further, only two U.S. astronauts have been

⁷ <https://advance.umich.edu/wp-content/uploads/2018/10/Handbook-for-Faculty-Searches-and-Hiring.pdf>

denied or pulled from a spaceflight assignment not due to health, family issues or personal career choice.

Airforce Ret. Colonel Yvonne Cagle, M.D. was never assigned a mission despite being a member of the military (all military astronauts have had missions). Dr. Jeanette Epps was removed from her mission to the international space station without explanation less than 7 months prior to launch and after training for over two years with Russian crew. Dr. Epps would have been the first African American assigned to a space station crew. I bring this account to my testimony on Achieving the Promise of a Diverse STEMM Workforce, because if such career altering acts that lack gatekeeper transparency and accountability can happen to exceptionally qualified in the rarified air and public visibility of NASA and the astronaut corps, we can only surmise what happens in the trenches of STEMM workforce.

H.R. 2653 The STEM Opportunities Act of 2017

I applaud the Congress for bringing forward this bill. It is timely and needed.

I offer the following comments to the bill based on my personal experiences and programs.

Organizations and agencies receiving taxpayer money, whether directly or through granting agencies, should be transparent on the numbers of men and women employed, in what capacities and job assignments. This data should be annual and available publicly. In addition, each should be required to develop a strategy and implementation plan with measurable objectives to achieve a workforce representative of the country. And the leadership must be held accountable for progressing steadily and with all due speed toward equity.

Education initiatives in STEM disciplines, especially K-12, should be maintained in individual federal agencies. For example, NASA, DOE, NOAA, NIH, NSF each bring their own expertise, resources, content and perspectives to the bear educating, supporting and inspiring teachers, students and public outreach in ways that cannot be duplicated through a single Department of Education mechanism. The knowledge of the disciplines, challenges and rewards is invaluable in fostering the STEM workforce.

Awareness of skilled technicians and labor in the STEM workforce should be highlighted and supported. Filling these jobs with the best talent benefits the country and individual citizens.

The Challenge

The challenge before us is to appropriately identify, commit to and incentivize the kind of coordinated, sustained, evidence-based action to ensure that we, as a nation, have full and unfettered access to develop the talent, benefit from the experiences and perspectives, and foster the goodwill of all people in this country with respect to the STEMM enterprise. We live in a time of great challenges-- poverty, hunger, disease, climate change, environmental degradation-- and in a country fueled by an “innovation economy.” STEMM has such a big impact on our shared prosperity and security, now more than ever, we need to take action, not only for the benefit of women and underrepresented minorities, but for the benefit of the nation and the world.

We must ask ourselves a simple question and be willing to act on the difficult answer.

“If we know that we need the full wealth and breadth of talent pool and there are effective policies and practices that institutions, organizations, and the country can adopt to improve the representation and experiences of women and underrepresented minorities in STEMM, why has the progress over the past decade been less than modest?”

Answer: Commitment and actions to effectively implement and sustain change means upsetting the status quo. Those comfortable, resourced, and well positioned in the existing culture- male and female, majority and minority—will be uncomfortable.

General Colin Powell reminds us in a lecture titled Great Lessons in Leadership, 1998 that ***“Being responsible sometimes means pissing people off.”***