The U.S. is a Keystone of Global Science & Engineering

As the National Science Board (NSB, Board) described in *Vision 2030*, the data in *Science and Engineering Indicators* show that the U.S. is at an inflection point as science & engineering (S&E) is increasingly global, demand for STEM talent rises, and knowledge- and technology-intensive industries grow. NSB's roadmap lays out the urgent action needed to ensure that the U.S. remains a global leader in S&E.

Science and Engineering Indicators 2022 shows that no nation is the world leader in all aspects of S&E. Instead of one country leading in most research areas or by most science and engineering metrics, nations now lead in some research fields, but not all, and by some metrics, but not by others. Going forward, countries will shift more rapidly and frequently in their positions in the discovery and innovation enterprise as many more nations participate, compete, collaborate, and contribute to the sum total of human knowledge. In this world, the U.S. no longer leads by default – our country must act intentionally to achieve its strategic objectives. Since across-the-board leadership in S&E is no longer a possibility, what then should our goals be?

The U.S. must be a **keystone** – an essential nexus that is instrumental to the structure and success of the global S&E ecosystem. The 2022 edition of *Science and Engineering Indicators* shows that the U.S. already is a keystone.

A keystone bridges nations and geographic regions, connects demographic groups and disciplines, and links sectors together. These connections germinate the next breakthrough discoveries, growing them from imagination to impact. This is how our country leads today and how the U.S. can continue to lead for the decades to come – if we take action now.

Talent is the treasure on which the nation's prosperity, health, and security depend. The diversity of our people, and the connections fostered between them, is a wellspring of American creativity in S&E – both for problem-solving, and for asking the next big questions. To be a STEM powerhouse, the U.S. must nurture talent in every state and across the many dimensions of diversity, particularly the "Missing Millions." For too long, too many Americans have encountered too many obstacles to pursuing education and careers in S&E. The U.S. must do better to provide opportunities for all. NSB's *Vision 2030* calls on policymakers to make K-12 STEM education a federal, state, and local priority, to ensure affordable and accessible post-secondary education, and to make S&E careers attractive and inclusive.

Missing Millions: Faster Progress in Increasing Diversity Needed to Reduce Significant Talent Gap

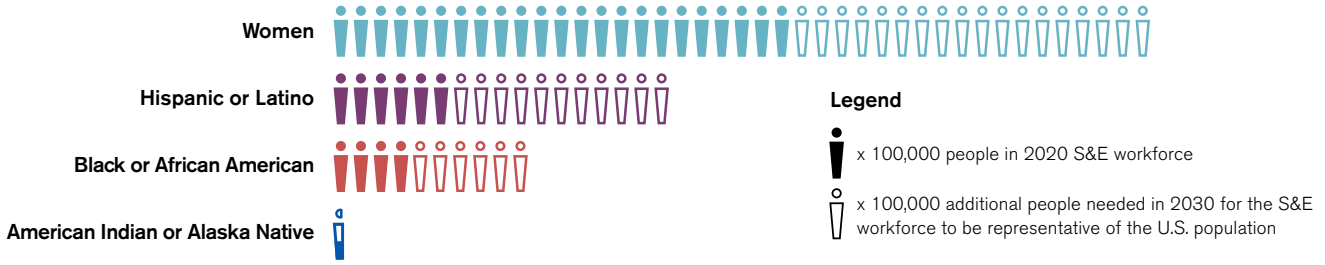

Figure 1: While the number of people from under-represented groups in the S&E workforce has grown over the past decade, much faster increases will be needed for the S&E workforce to be representative of the U.S. population in 2030. To achieve that goal, the NSB estimates that the number of women must nearly double, Hispanic or Latinos must triple, Black or African Americans must more than double, and the number of American Indian or Alaska Native S&E workers needs to quadruple (from 15,000 to 60,000). The NSB estimates that the number of Native Hawaiian or Other Pacific Islanders will be slightly overrepresented in the S&E workforce in 2030. These estimates are based on projections from the U.S. Census and Bureau of Labor Statistics, together with data from the 2021 Women, Minorities, and Persons with Disabilities in Science and Engineering report published by the National Center for Science and Engineering Statistics and assume that participation of these groups in the S&E workforce increases at current rates.

Closing the gap for the Missing Millions includes addressing the earliest step on the STEM pathway: K-12 STEM education. At a time when the U.S. economy and the nation's global competitiveness increasingly depend on math and science knowledge and skills, American children have continued to fall behind, with major disparities in math performance based on race, ethnicity, and socioeconomic status (SES).

Disparities in family wealth are reflected in the test performance of children. Students who are eligible for free- or reduced- lunch have lower average scores than their higher-SES counterparts – and strikingly, amongst students from low-SES families, *no* racial or ethnic group achieves proficiency. Furthermore, the average scores of children from the Missing Millions racial and ethnic groups are consistently lower than their white and Asian peers at the same SES level.

Geographic disparities are also apparent in test performance, with students in the Northeast scoring higher than students in the South and West, and students in suburban schools scoring higher than students in rural, town, and city schools.

Addressing the persistent educational inequities that exist across dimensions of geography, race, and economic background is both an ethical and economic imperative for our country.

Average Scores for 8th Grade Students on the NAEP Mathematics Assessment, by Ethnicity and Eligibility for Free or Reduced Lunch

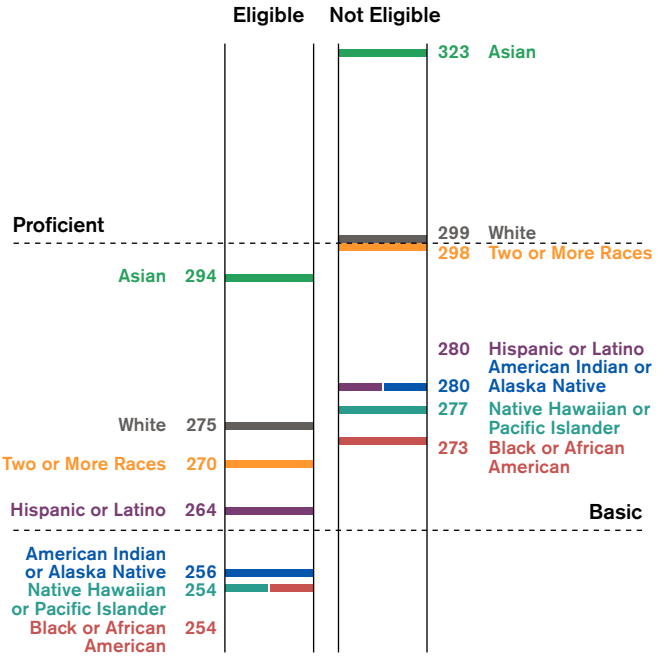

Figure 2: 2019 National Assessment of Educational Progress (NAEP) mathematics assessment. NAEP achievement levels are defined as Basic: 262-298; Proficient: 299-332; Advanced: 333-500. NAEP is a congressionally mandated program administered by the National Center for Education Statistics and overseen by the National Assessment Governing Board.

S&E Degrees Awarded by Sex and Field

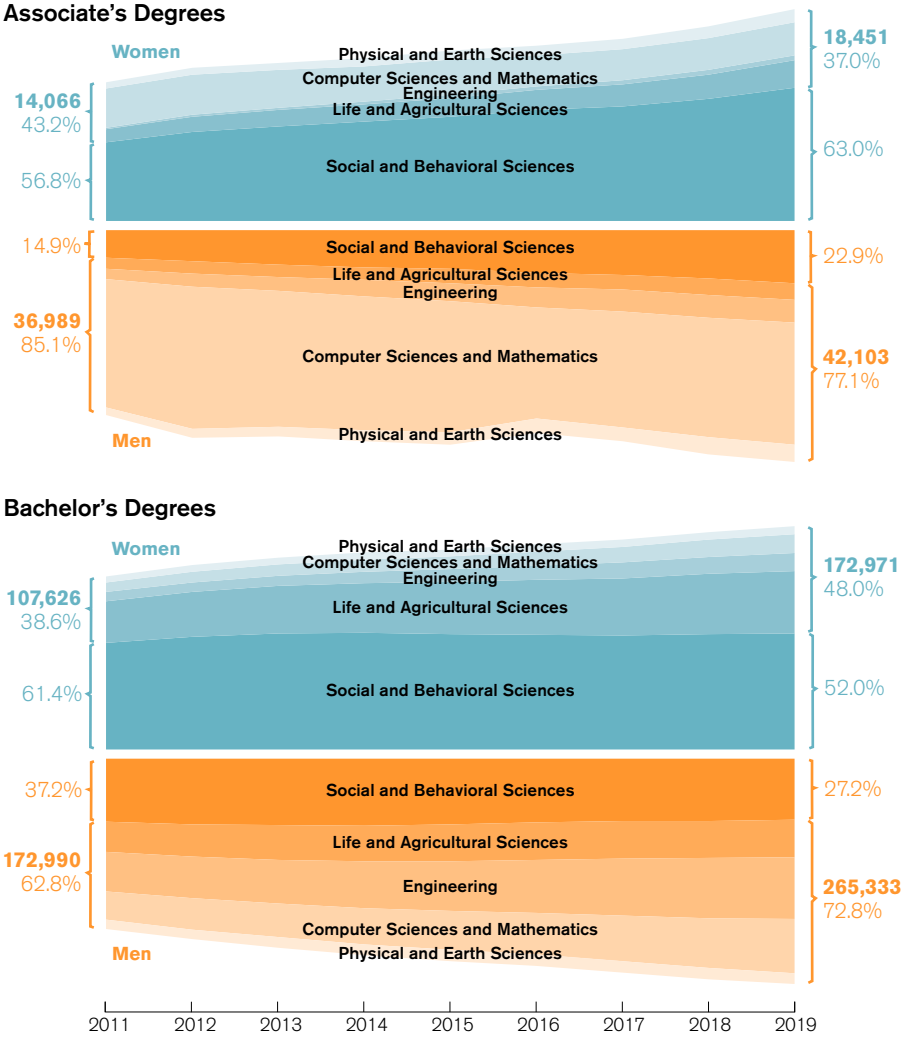

Figure 3: S&E associate's and bachelor's degrees awarded in the U.S. by sex and discipline, 2011-2019. In 2019, 104,435 associate's and 724,947 bachelor's S&E degrees were awarded, of which 3% of associate's and 7% of bachelor's went to temporary visa holders. The number of women earning S&E associate's and bachelor's degrees has increased significantly since 2011. At both levels, a majority of the S&E degrees earned by women are in the Social and Behavioral Sciences, whereas this field accounts for only a quarter of the S&E degrees earned by men.

The Missing PhDs: Gaps by Race/Ethnicity and Field

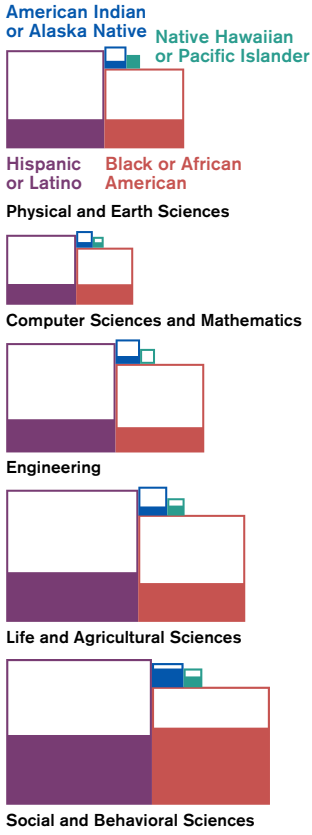

Figure 4: Within each field, the boxes for race or ethnicity are sized to their relative proportion in the overall U.S. population. The solid color area within each box represents the number of doctorates awarded (2018) in the given demographic for that research field; unfilled area represents the number of additional doctorates from that demographic needed for the field to be representative of the group's proportion in the U.S. population. The box sets are scaled to illustrate the relative number of doctorates awarded to U.S. citizens and permanent residents across these degree fields.

Where are the millions missing? At all levels of STEM higher education, long-standing disparities persist. Women, both domestic and foreign-born, receive fewer post-secondary degrees in engineering, math, and computer science – fields that underlie many critical and emerging areas in science and technology. Hispanic or Latino, Black or African American, American Indian or Alaskan Native, and Native Hawaiian or Pacific Islander students are also underrepresented across S&E fields, including at the doctoral level. These disparities arise from long-standing issues including, but not limited to, bias, lack of mentoring and role models, STEM teaching practices, underpreparation in K-12 leading to difficulty in transitioning to post-secondary education, and college affordability.

College cost, coupled with insufficient information about the labor market demand for STEM skills in a wide range of jobs, deter undergraduates from starting and/or completing STEM degrees. Fifty-five percent of bachelor's degree recipients graduate with student debt, which can impact the educational choices of *all* students from lower-SES backgrounds. These students, including a disproportionate number of individuals from Missing Millions racial and ethnic groups, have little to no intergenerational wealth to draw on for their educational goals.

As part of a comprehensive strategy to diversify and strengthen the U.S. domestic S&E workforce, S&E leaders and policymakers should work to make all levels of higher education an attractive, inclusive, and financially sustainable choice for individuals from all backgrounds.

Geography of S&E

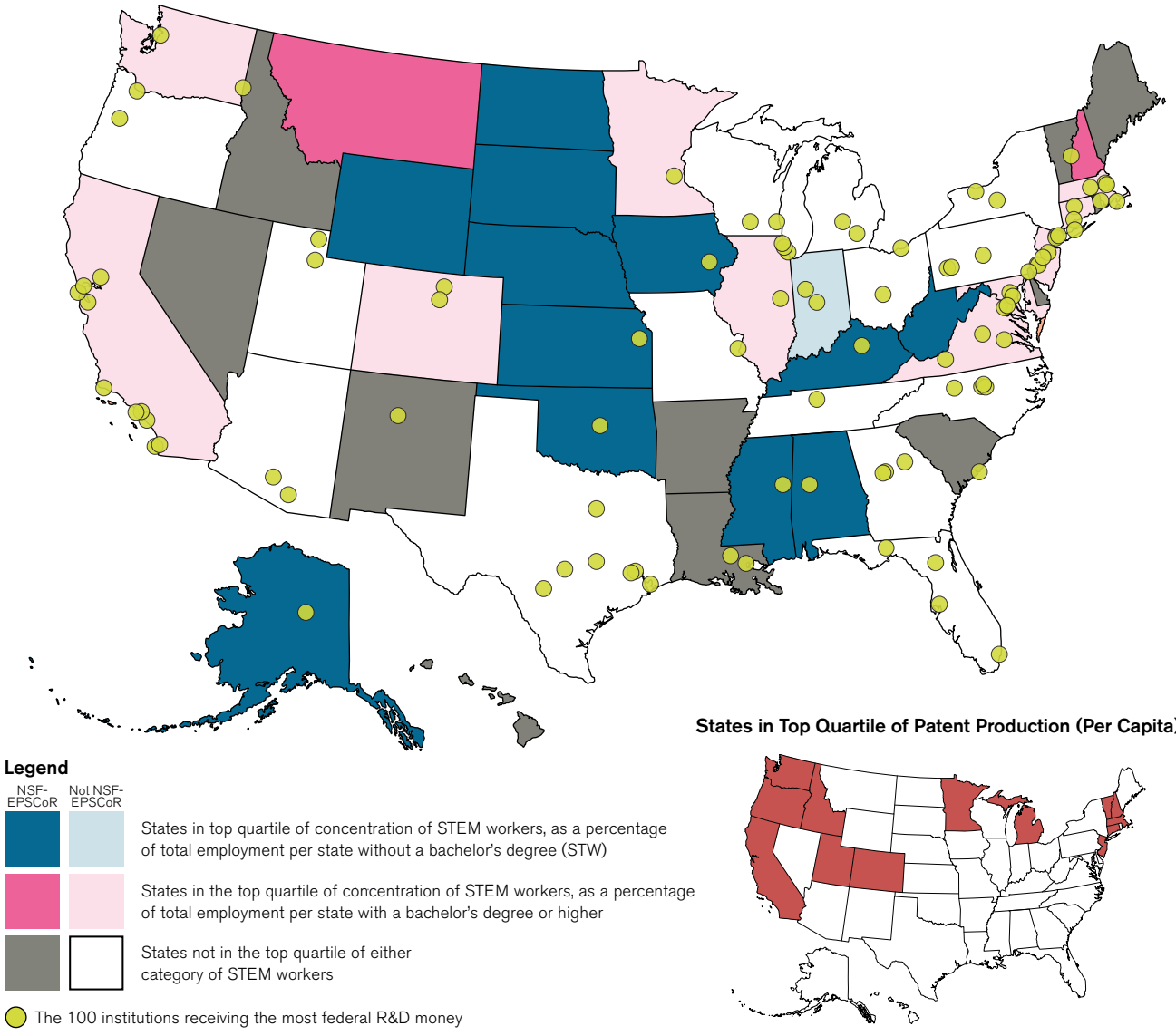

Figure 5: Geography of federal R&D funding to institutions of higher education; states eligible for NSF's Established Program to Stimulate Competitive Research (EPSCoR) program in 2019; concentration of STEM workers, as a percentage of total employment per state, with and without bachelor's degrees in 2019. Geography of concentration of patents per capita in 2019 (inset).

The geography of S&E in the U.S. is diverse, with strengths and opportunities that vary across states. Some states are home to a high proportion of skilled technical workers (STW), while others have a high proportion of workers with S&E degrees at the bachelor's level or above. Many states host institutions of higher education that receive a substantial amount of federal R&D funding, and some states have high rates of patenting. Many states have combinations of these features, adding to the variety and richness of the nation's S&E landscape.

The U.S. S&E enterprise is an engine of economic growth both for the country and for individuals. For example, jobs requiring S&E knowledge and skills (both for those with and without a bachelor's degree) pay more on average and were more resilient during the COVID-19 pandemic-related economic downturn compared to non-STEM jobs. Every state has some S&E assets and expertise – in industry, in higher education, in the workforce – and leveraging these local capabilities will be key to expanding the geography of innovation. To ensure that *all* Americans can participate in and benefit from the S&E economic engine, the U.S. must invest in public K-12 and post-secondary STEM education in every state and strategically develop capacity by establishing innovation hubs across the country.

While developing domestic talent, the U.S. must continue to welcome foreign S&E talent – an essential element to maintain the nation's S&E keystone position. The U.S. has been the premier developer of global STEM talent, in no small part due to federal support for S&E research, which annually funds tens of thousands of researchers and students through grants, programs, and research facilities. International students are particularly prevalent in fields that underpin critical and emerging technologies, such as engineering, computer science, and math.

While the total number of PhDs awarded increased through 2018, international student enrollment in the U.S. has declined since 2019, most precipitously during the COVID-19 pandemic. It is not a foregone conclusion that international students will continue to come to the U.S. at the same rates as before, as other nations increasingly offer attractive options to these individuals. To remain a magnet for international talent, the U.S. must have a clear, consistent, and predictable visa system, and ensure that those who come here feel welcome and secure.

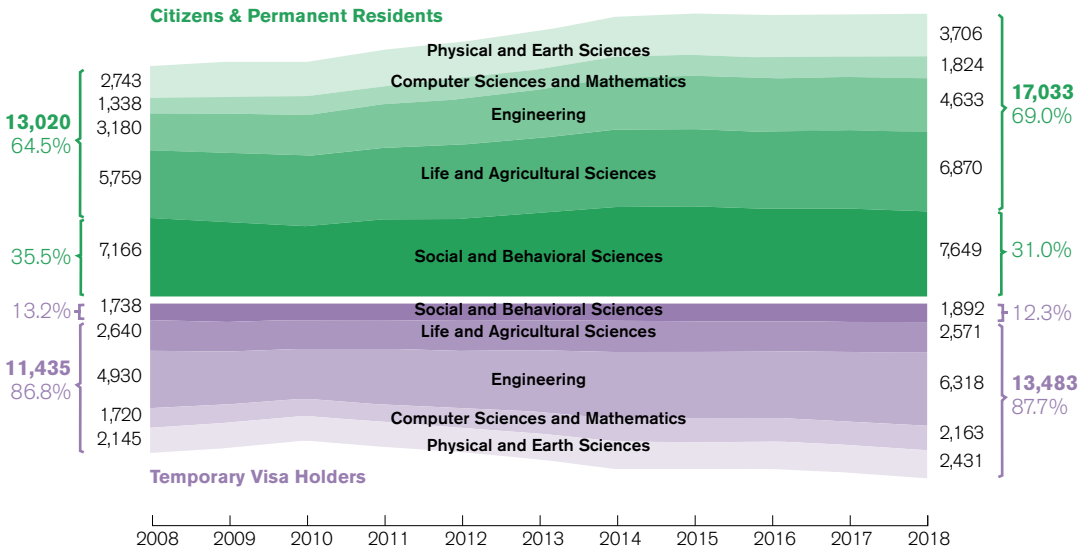

Figure 6: Science and engineering PhDs awarded, by citizenship and field: 2008-2018. Green: PhDs awarded to U.S. citizens and permanent residents. Purple: PhDs awarded to temporary visa holders. Numbers of doctorates awarded in each field are shown for 2008 (left) and 2018 (right). The number of S&E doctoral degrees awarded to U.S. citizens and permanent residents has increased significantly since 2008. During this period, Social and Behavioral Sciences doctorates decreased from 35% to 30% of S&E degrees awarded to domestic students. The total number of S&E doctorates awarded to international students increased more slowly, and the percentage awarded in the Social and Behavioral Sciences held steady at approximately 13-14%.

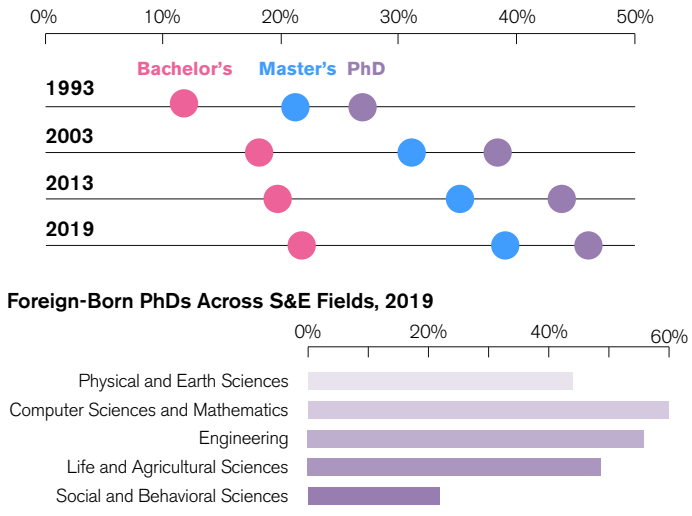

Figure 7: Foreign-born workers in the U.S. S&E workforce. Top: share of foreign-born S&E workers by degree type (bachelor's, master's, and PhD). Bottom: percent of S&E workers holding a doctoral degree who are foreign-born, by field.

Many international students who come to the U.S. to study stay and join the U.S. S&E workforce. The share of foreign-born S&E workers has increased significantly in the last 25 years. In most S&E occupations, the higher the degree level, the greater the proportion of the workforce that is foreign-born.

Most U.S.-educated foreign S&E doctorate holders work in R&D for large private companies and are employed in the same fields as their doctorates. In computer science, mathematics, and engineering, nearly 60% of PhD holders in the U.S. workforce are foreign-born, a group that includes naturalized citizens and long-term residents as well as visa holders. They are significant contributors to the U.S. economy and the nation's global competitiveness in S&E – and are indispensable if the U.S. is to hold and strengthen its position as a keystone of global S&E.

Knowledge- and technology-intensive (KTI) industries develop and deploy many of the critical and emerging technologies essential for current and future U.S. competitiveness. To cement its position in these industries as a keystone of global S&E, the U.S. must collaborate strategically with like-minded partners and build a workforce that can bring a diversity of perspectives. Doing so will enable the U.S. to set norms and practices for these new technologies that enhance their benefits and reduce potential harms.

Currently, KTI industries employ 5.7 million S&E workers – fully 18% of the U.S. STEM workforce in 2019 – but millions more are missing from this critical workforce. These industries employ only 22% women and 16% people from underrepresented ethnic and racial groups, and they depend on foreign-born talent, who made up 26% of their S&E workers in 2019. In degree fields that are vital to critical and emerging technologies, such as artificial intelligence and biotechnology, it is imperative that the U.S. actively embrace equity in its domestic talent development strategy. At the same time, the U.S. must continue to attract the talent from around the world that has long been – and will continue to be – essential to the U.S. economy and our S&E ecosystem.

Demographics of S&E Workers in Selected KTI Industries

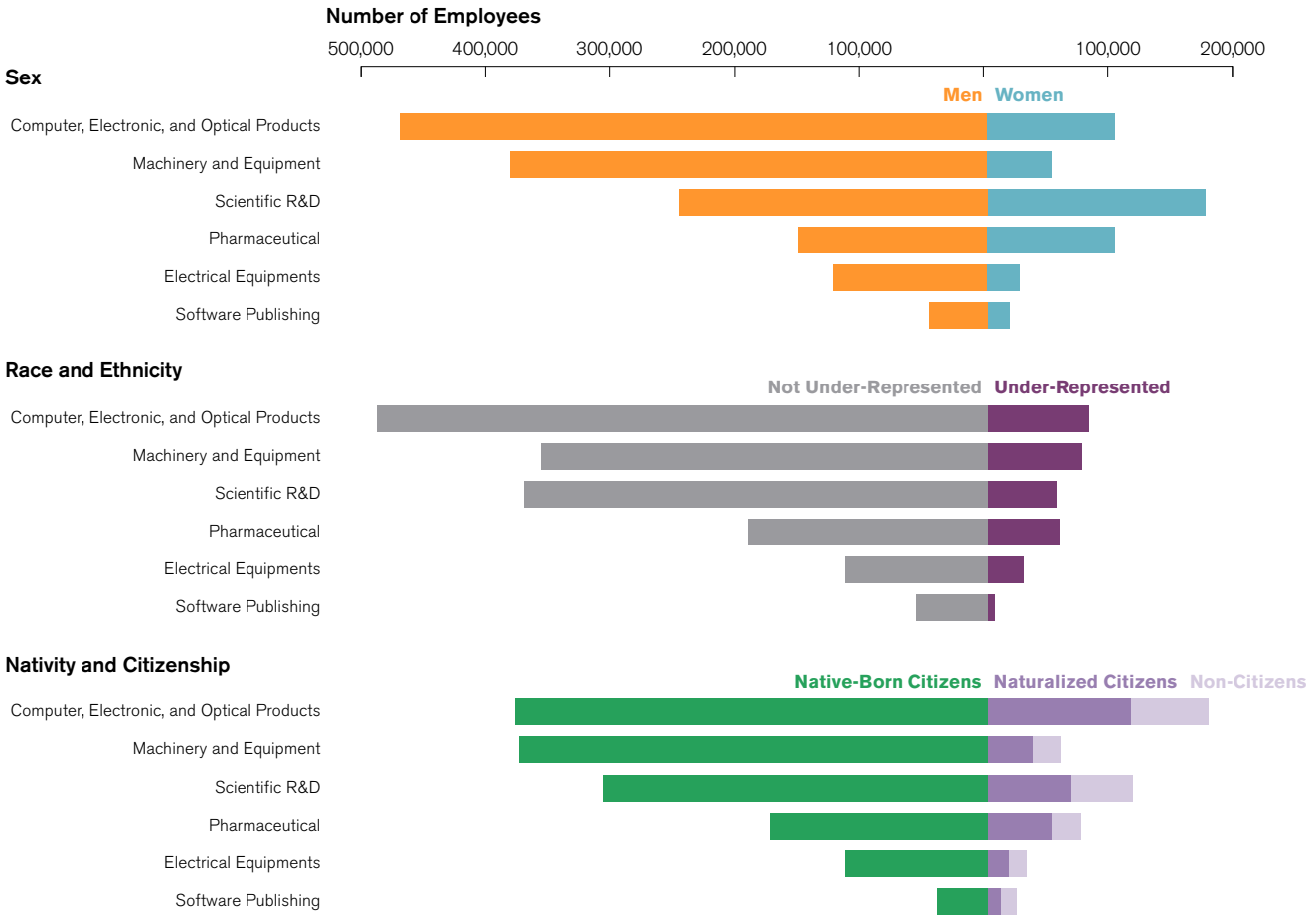

Figure 8: 2019 STEM worker employment in KTI industries, including workers with and without bachelor's degrees, by sex, race or ethnicity, and nativity and citizenship. Includes workers aged 16-17 not in military occupations or enrolled in primary or secondary school. "Underrepresented groups" includes Blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives.

The long-standing U.S. investment in basic research is fundamental to our country's standing as a keystone of global S&E. The U.S. is still by far the global leader in expenditures on **basic** research, outspending China three-fold. But while overall funding of R&D in the U.S. continues to rise rapidly, the share of basic research funded by the federal government is declining. This matters because business investments in basic research focus on just a few areas that have a high potential for leading to new or improved technologies in the near-term, such as computing, pharmaceuticals, and transportation.

Today's R&D-intensive industries exist, in part, because the federal government invested in basic research long before the research had a known application. Only the federal government can make this strategic, long-term investment to create new knowledge, supporting risks that are difficult for the private sector to undertake. Robust federal investment in basic research across all fields will ensure that the significant share of the scientific breakthroughs and innovations that will shape our global future are "Made in America."

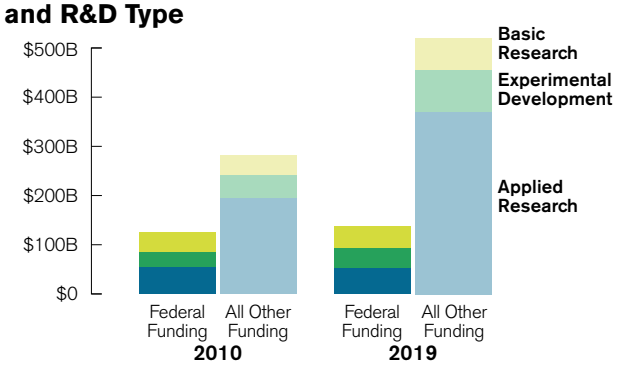

Figure 9: U.S. R&D performance funded by the federal government and by all other sources, by type of R&D, 2010 and 2019. Federal investment in basic research increased from $40.2B in 2010 to $43.9B in 2019 in current dollars; taking inflation into account, real expenditures have decreased. The share of basic research funded by the federal government also decreased, from 52.3% in 2010 to 40.7% in 2019.

Even as America's share of global spending on R&D has decreased as more countries invest in S&E, the U.S. remains at the center of the global web of S&E collaboration. In times of crisis and opportunity alike, the world's scientists and engineers partner with their American colleagues. For example, analysis of coronavirus-related publications in 2020 shows the centrality of the U.S. to the global research effort. It also illustrates the strong collaboration between the U.S. and researchers around the world, most notably in China and the UK.

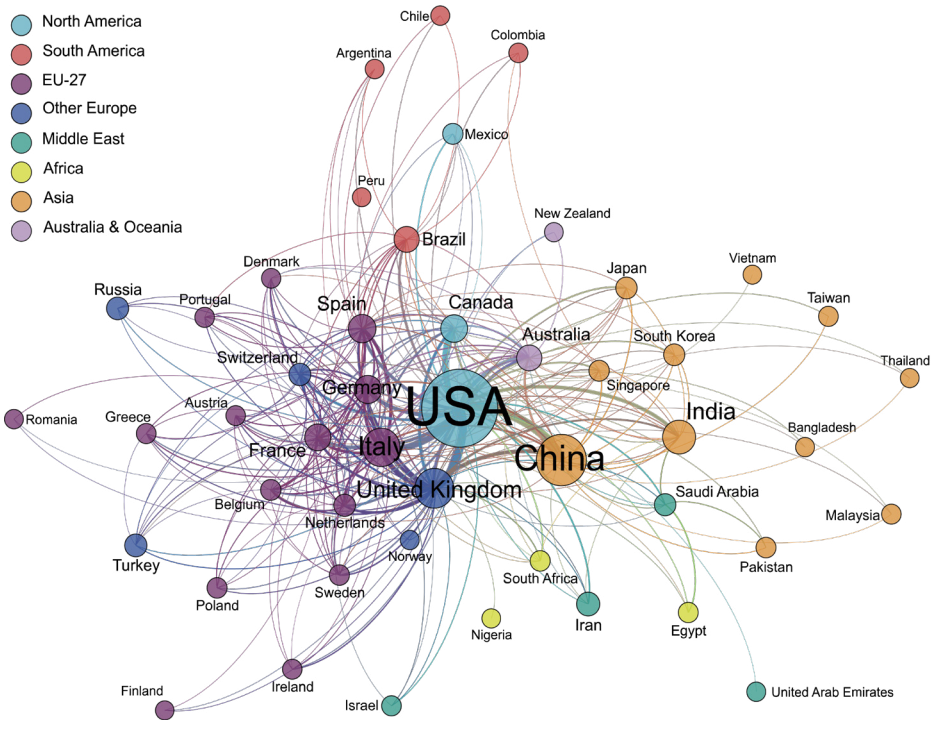

Figure 10: Network diagram of the network of coronavirus collaboration in 2020 for the 50 countries with the most coronavirus-related research publications who also cowrote 50 or more articles. Node size is proportional to the total number of coronavirus-related articles written by each country. Link thickness between nodes is proportional to the quantity of cowritten papers. Distance between nodes indicates relatedness of countries.

As the U.S. builds and strengthens domestic public/private partnerships to respond to a more competitive global S&E landscape, we must also retain and strengthen the nation's position as a key hub of international collaborations and partnerships. These collaborations foster S&E on a global scale, train the next generation of R&D workers, bring cultural, economic, and political benefits, and allow the U.S. to leverage its resources in the operation of costly large-scale research facilities. A strong U.S. presence also strengthens global acceptance of the core values of open, transparent, and ethical conduct of S&E research.

What does it mean to be a keystone of global S&E? It means strengthening international collaborations and engagements, not withdrawing from them. It means being a dependable partner and responsibly fostering open exchanges of ideas and people across fields, public and private sectors, and borders. It means being a hub of the worldwide S&E talent flow. It means collaborating with like-minded countries to set the values, norms, and practices – the rules of the road – for research, and living those values ourselves.

Being a keystone nation means becoming an example of a truly inclusive enterprise that welcomes and nurtures all talent. It means doing the work to dismantle systemic barriers that too many have faced for too long. As policymakers and leaders of the U.S. S&E community, we must hold ourselves, and each other, accountable for progress in developing the next generation of diverse STEM talent. We must work together to set meaningful goals across the educational continuum – from K-12 through doctoral degrees. We must collect data that will allow the measurement of progress and we must be transparent by making the goals, data, and progress publicly available.

As a keystone nation, the United States must be the place where all talent is given the opportunity, freedom, and resources to innovate, take risks, and collaborate. A place where researchers can explore without knowing in advance what discoveries may result, but sure in the knowledge that the fruits of research will help solve societal challenges, deliver near-term innovations, and bring long-term benefits to Americans and all of humanity.

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