

Building America's STEM Workforce

Eliminating Barriers and Unlocking Advantages



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EXECUTIVE SUMMARY

Once the uncontested global leader in science, technology and innovation, the United States now faces a very different competitive landscape. The combination of increasing competition for international talent and our own inaction to address inequalities in education and research opportunities domestically is hindering our future prospects of remaining a global leader in science, technology and innovation, and is jeopardizing the economic and social prosperity it generates.

This report synthesizes a wide array of publicly available data and reports—complemented with surveys of physics department chairs and APS members—to generate an understanding of a set of current challenges and opportunities for action related to building America’s STEM workforce. The challenges are clear and significant—we have an urgent shortage in qualified STEM teachers, the distribution of federal research investments amplifies systemic inequities, there are hostile workplaces and pathways throughout the scientific ecosystem, and our outdated visa and immigration policies dissuade, rather than attract, international talent.

The world is changing, and simply continuing the status quo will not suffice. Doing so will result in our nation’s scientific enterprise steadily losing its most critical R&D assets—talented human capital, both domestic and international, and the innovations they generate. Increased efforts and new evidence-based federal policies aimed at bolstering our overall STEM workforce are required to ensure the United States continues to be a global leader in science, technology and innovation.

To be clear, we are not facing a choice between bolstering either our domestic or international workforce. It is not an either/or decision. Challenges for both segments must be addressed to create the 21st century workforce needed to maintain America’s global leadership. We must increase the number of qualified STEM teachers to meet the needs of our high schools; broaden research opportunities for students from underrepresented groups in a sustainable manner; improve the atmosphere of our laboratories and work environments for women and underrepresented groups; and restore our country as the premiere destination of global talent through an intentional STEM visa and immigration policy that encourages the world’s best and brightest minds to come and stay in the United States.

INTRODUCTION

Today, the global landscape is remarkably different from what it was at the turn of the century, and with the pace of scientific discovery and commercialization accelerating, it is extremely competitive. The United States can no longer claim to be the undisputed global leader in science, technology and innovation. The Global Innovation Index 2020 ranks the United States 3rd among other countries [1], and our nation now sits 8th in gross domestic expenditure on research and development (R&D) as a percentage of GDP, according to the OECD's Main Science and Technology Indicators [2].

Our innovation-driven economy relies on our continued global leadership in science and technology (S&T), with more than 85% of the long-term growth of the US economy attributed to advances in S&T. [3] But as many of our competitor nations increase their investments in their own R&D enterprises, US investments in both R&D and the associated workforce have stagnated as a function of GDP during the last several decades [3].

As our share of global R&D investment continues to decrease, highlighted by the estimation that China surpassed the United States in R&D investment in 2018, [3] we are failing to capitalize on—or actively neutralizing—our competitive advantages. The percentage of women and people of underrepresented minorities working in S&T fields, for example, is well below their share of the college-educated workforce and the national demographics. [4] And despite the considerable contributions international students and scientists have made to the United States, recent federal policies have limited their opportunity to study and work here.

For the United States to remain a global leader, simply continuing the status quo will not suffice. Doing so will result in our nation's scientific enterprise steadily losing its most critical R&D assets—talented human capital, both domestic and international, and the innovations they generate. Increased efforts and new federal policies aimed at bolstering our overall STEM workforce are required to ensure the United States continues to be a global leader in science, technology and innovation.

We synthesized a wide array of publicly available data and reports—complemented with surveys of physics department chairs and APS members—to generate an understanding of a set of current challenges and opportunities related to our nation's STEM workforce. The set of challenges outlined in the forthcoming pages is not intended to be exhaustive, and while the issues facing our domestic and international segments differ, in each case they negatively impact the United States' ability to develop its next-generation workforce. Choosing between bolstering either our domestic or international workforce is not an option. We must do both.

Our findings compel meaningful, timely action, and we present a series of actionable recommendations—including many which do not require additional resources—that will foster the robust, diverse STEM workforce the United States needs to maintain its global leadership in science, technology and innovation.

DOMESTIC WORKFORCE

US-born professionals represent approximately 70% of the US Science and Engineering (S&E) workforce. The US S&E workforce is growing at a faster pace than the workforce overall [4], and the country faces a persistent and dramatic shortage of STEM workers. [5] While there has been progress, the participation of women, racial and ethnic minorities, and rural Americans in the US scientific and technical workforce does not reflect the diversity of our population. [4] We are failing to capitalize on, or actively neutralizing, one of our key competitive advantages—our nation’s diversity. Their underrepresentation negatively impacts the US R&D enterprise by depriving it of diverse perspectives that are shown to boost innovation and productivity. [6] [7] Developing a diverse 21st century workforce and building an inclusive innovation infrastructure—one that expands our research capacity in a way that best enables broad participation in taking a new idea from initial experiments all the way to the marketplace—are essential both to enhance our economic competitiveness and address societal needs. To remain a global leader in science, technology and innovation, we must address the lack of representation in the STEM workforce through actions at all levels, from individual practices to federal policies. We highlight three challenges that can be matched with actions by the federal government in the near term.

United States Urgently Needs More STEM Teachers

Approximately 3.2 million students graduated high school in the spring/summer of 2019. Of these new graduates, more than 65% enrolled in college the following fall. [8] These young future professionals are key to solving the national shortage of STEM professionals, but the US K-12 system is not properly preparing most of them for the task. According to ACT, only 20% of graduates with an intent to pursue a career in STEM are ready to succeed in their first year as students in a STEM degree. [9] In 2019, this statistic translated to the K-12 education system underpreparing more than half a million young aspiring STEM professionals.

In 2018 alone, the projected US production of qualified STEM teachers is 110,000 teachers short of the demand. [10] This shortage is impacted by the high attrition rate within the US teacher workforce, almost twice that of other high-achieving countries. [11] Additionally, teachers of STEM disciplines are often unprepared in the content of the subject area they are assigned to teach. In 2011-2012, **approximately two thirds** of the teachers for Physics, Chemistry, Physical Sciences, or Earth Sciences **did not** have either a major or minor in the subject area or were not certified. [12] [13] Moreover, the teacher shortage is much more severe in low-income schools, amplifying societal inequalities. [10] While there is not a single, simple solution to solve this problem, addressing the chronic and growing shortage of qualified STEM teachers in the United States must be included in any meaningful solution.

Figure 1: US Shortage of Well-Prepared STEM Teachers

Subject	Number of Teachers	Percent with major or minor and/or certification in main subject area
Physics	13,300	37%
Biology	21,900	65%
Chemistry	24,300	34%
Physical Science	64,600	38%
Science	126,300	73%
Math	144,800	62%

Adapted from: M. Marder, R. C. Brown and M. Plisch, "Recruiting Teachers in High-needs STEM Fields: A Survey of Current Majors and Recent STEM Graduates," American Physical Society Panel On Public Affairs, 2017.

Federal R&D Investments Distribution Amplifies Inequities

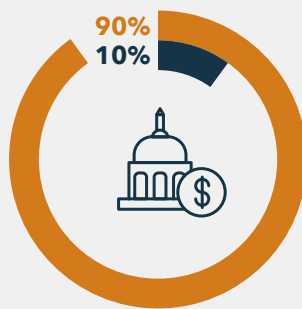
Participation in research is a high-impact practice for workforce strengthening and diversification. Yet, historically, the majority of federal research funding has been distributed to a fraction of our country's research universities. In 2018, for example, of the more than 600 colleges and universities that received federal science and engineering funding, approximately 22% received more than 90% of federal science and engineering funding [14] while only serving 43% of all students and 34% of the nation's underrepresented minority (URM) students. [15] This discrepancy results in students at the approximately 500 remaining colleges and universities, including almost **two thirds of the nation's URM students and more than two thirds of Pell grants recipients**, having either limited or no opportunity to engage in research. We are forgoing the opportunity to train them to be part of the much-needed workforce of emerging industries, including quantum information science and artificial intelligence.

Figure 2: Federal Investments in Science and Engineering R&D Amplifies Systemic Inequalities

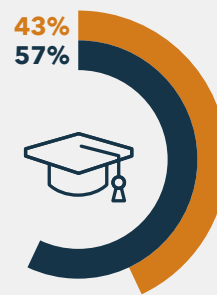
In 2018, 637 Institutions Received Federal Funding for Research and Development in Science and Engineering

■ top 22%

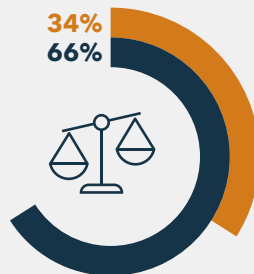
■ Emerging Research Institutions



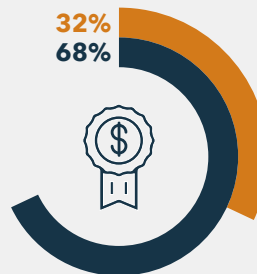
% of federal S&E R&D funds received



% of total students served



% of total URM students served



% of Pell grant recipients served

Compiled from publicly available data from NCES at: <https://ncesdata.nsf.gov/herd/2018/> AND <https://nces.ed.gov/ipeds/datacenter/InstitutionByGroup.aspx>

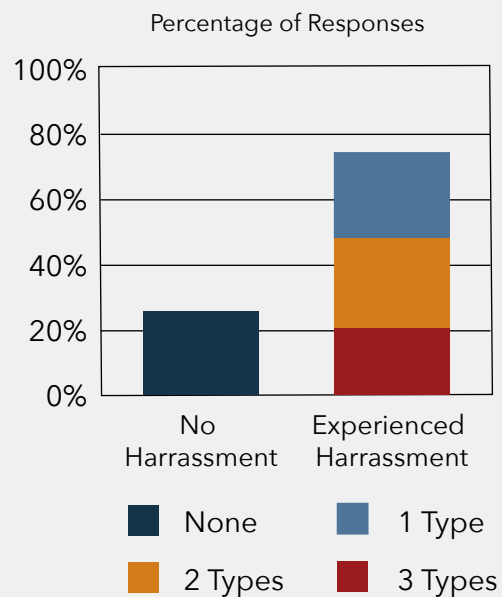
Hostile Work Environments are a Barrier for Women in STEM

In addition to unequal access to research opportunities and training, studies show that there are systemic and cultural aspects of the current R&D ecosystem that negatively contribute to an inclusive and productive career environment. [16] [17] [18] In particular, women accounted for approximately 52% of the college-educated workforce in 2017, but they only made up 29% and 16% of the physical sciences workforce and engineering workforce, respectively. [4] This lack of representation negatively impacts innovation and cannot be solely attributed to inequities in education or the workforce pipeline. In physics, for example, a recent survey [19] of undergraduate women in physics found that nearly **75% of respondents had experienced at least one type of sexual harassment.**

Figure 3: 2018 Study Shows Vast Majority of Undergraduate Women in Physics Experience Sexual Harrassment

75% of respondents had experienced at least one of the following types of sexual harassment:

- sexist gender harassment, which includes experiences that are primarily discriminatory based on one's gender;
- sexual gender harassment, which encompasses sexually explicit behavior without sexual advance; and
- unwanted sexual attention.



Adapted from: L. M. Aycock, Z. Hazari, E. Brewster, K. B. Clancy, T. Hodapp and R. M. Goertzen, "Sexual harassment reported by undergraduate female physicists," Phys. Rev. Phys. Educ. Res., vol. 15, p. 010121, 2019.

Sexual harassment undermines career advancement for women. Additionally, women who are members of racial or ethnic minority groups are more likely to experience sexual harassment and to feel unsafe at work than white women, white men, or men who are members of racial and ethnic minority groups.

What We Can Do

The aforementioned challenges are not intended to be an exhaustive list, but addressing these issues is essential to any successful strategy for bolstering our domestic workforce. While professional societies and other organizations are working to help address these issues, action also is required from the federal government. APS, for example, recently co-produced a report on successful teacher preparation practices [20] and a recent study [13] that showed that more than half of STEM majors have an interest in teaching but that most are choosing not to pursue a teaching career due to career misconceptions, lack of financial support, and a lack of teacher preparation programs. These efforts inform and highlight the need for action by the federal government in enhancing teacher preparation pathways and programs.

To create the 21st century workforce needed to maintain America's global leadership, we must increase the number of qualified STEM teachers to meet the needs of our high schools; broaden research opportunities for students from underrepresented groups in a sustainable manner; and improve the atmosphere of our laboratories and work environments for women and underrepresented groups. The following policy recommendations address each pressing issue.

Increasing Qualified STEM Teachers

- Provide federal agencies the funding necessary to expand and sustain high-quality STEM teacher preparation programs at colleges and universities, similar to the NSF Robert Noyce Teacher Program Capacity Building grants.
- Provide federal agencies the funding necessary to increase teacher preparation scholarships and fellowships, such as the NSF Robert Noyce Teacher scholarships and fellowships grants, and expand teacher student loan forgiveness to appropriate levels that address the magnitude of the US teacher shortage.

Broadening Opportunities by Building Research Capacity

- The solution is not to reduce funding to research-intensive institutions. Instead, we must increase our R&D investments overall, while also adjusting their distribution.
- Agencies should enable and incentivize our top research universities to create meaningful lasting partnerships that strengthen the research capacity at emerging research institutions, including minority-serving institutions (MSIs), tribal colleges and universities (TCUs), historically black colleges and universities (HBCUs), and the colleges and universities with smaller research activities, which are often in underserved states. To facilitate a large participant pool, these partnerships should not be limited geographically.
- Agencies should strongly encourage research proposals directly from emerging research institutions.
- Agencies should track statistics on awards to emerging research institutions.

- Agencies should conduct a comprehensive portfolio analysis of the awards for emerging research institutions and identify best practices and methodologies for increasing funding to these institutions.

Improving Inclusivity in Laboratories and Work Environments

- Congress should reintroduce and pass the Combating Sexual Harassment in Science Act of 2019.
- Agencies should adopt and implement policies consistent with the NSF's update of terms and conditions: Sexual Harassment, Other Forms of Harassment, or Sexual Assault [21].

INTERNATIONAL WORKFORCE

For the last several decades, the United States has been a premier destination for talented international students and scholars. The benefit international students and researchers provide to the United States is clear and measurable. Foreign-born STEM professionals are critical to the US R&D ecosystem, and our economy and society more broadly. They bring fresh perspectives, diverse experiences, expertise, new ideas, and creativity to our universities, laboratories, and companies. As of 2018, immigrants had founded more than half (50 of 91) of the privately held billion-dollar startup companies in the United States, with 21 having a founder who first came to the United States as an international student. [22] As a result, they have promoted job growth, [23] generated higher average salaries for US workers, [24] and become an indispensable part of US high-tech competitiveness. [25]

However, recent federal policies have limited the opportunities for foreign-born scientists and engineers to come to the United States. APS conducted surveys and gathered testimonials from both domestic and international members to better understand the detrimental effects that these policies are having on our ability to attract and retain talented international students and scholars. The survey results and stories provide a better understanding of the importance that foreign-born STEM professionals have in our innovation ecosystem, bring to light the consequences of recent federal policies, and identify specific policies that can be implemented to help ensure the United States remains the destination of choice for the world's best and brightest.

Importance of International Students and Scholars

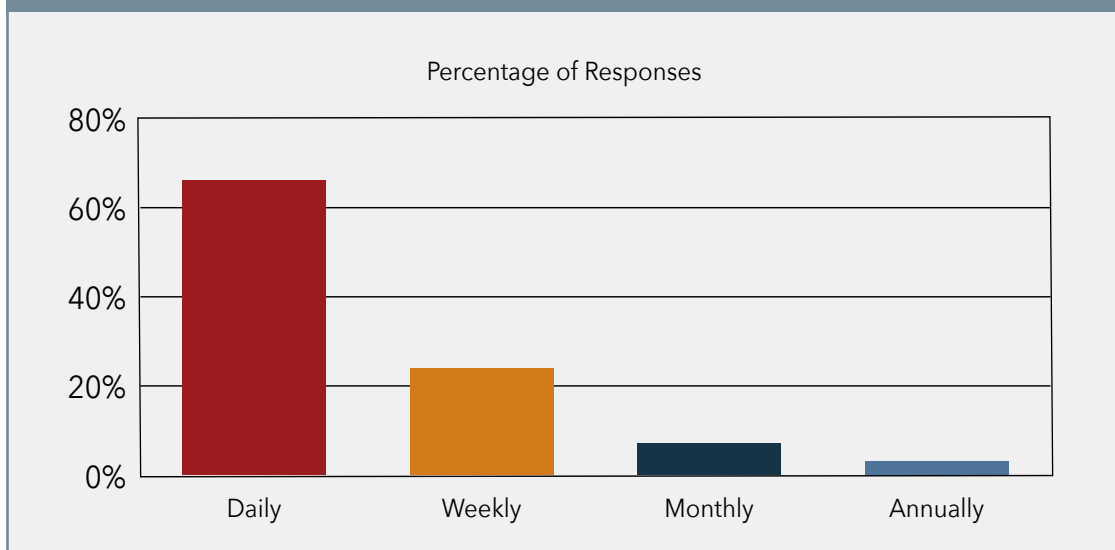
American scientists—who work side-by-side with international students and scholars—clearly recognize the value that they provide to our scientific enterprise. According to a 2020 survey of more than 300 domestic student and early career APS members who regularly interact with their international counterparts, more than 90% strongly agreed that international students and scholars make important contributions to research conducted in the laboratory. Additionally, more than 85% strongly agreed that international students and scholars are important to their personal experience as a student or researcher. Survey respondents noted that strong scientific knowledge (85%), new ideas (79%), diverse points of view (85%), and cultural exchange (89%) are among the key benefits international scholars bring to the US research enterprise.

APS recently asked its members to share the impacts that the J-1 visa and Optional Practical Training (OPT) programs have had on their or their peers' careers. The Society received more than 100 compelling letters, including approximately half from US citizens, [26] featuring personal stories that highlight the importance of foreign-born scholars to the United States. **Taken together, the studies, survey results and personal letters convey a clear message international students and scholars are critical to the US scientific enterprise, as well as our society more broadly.**

“Bringing an excellent scientist from around the world doesn’t just mean we gain one scientist, it means all of science in the US is stronger.”

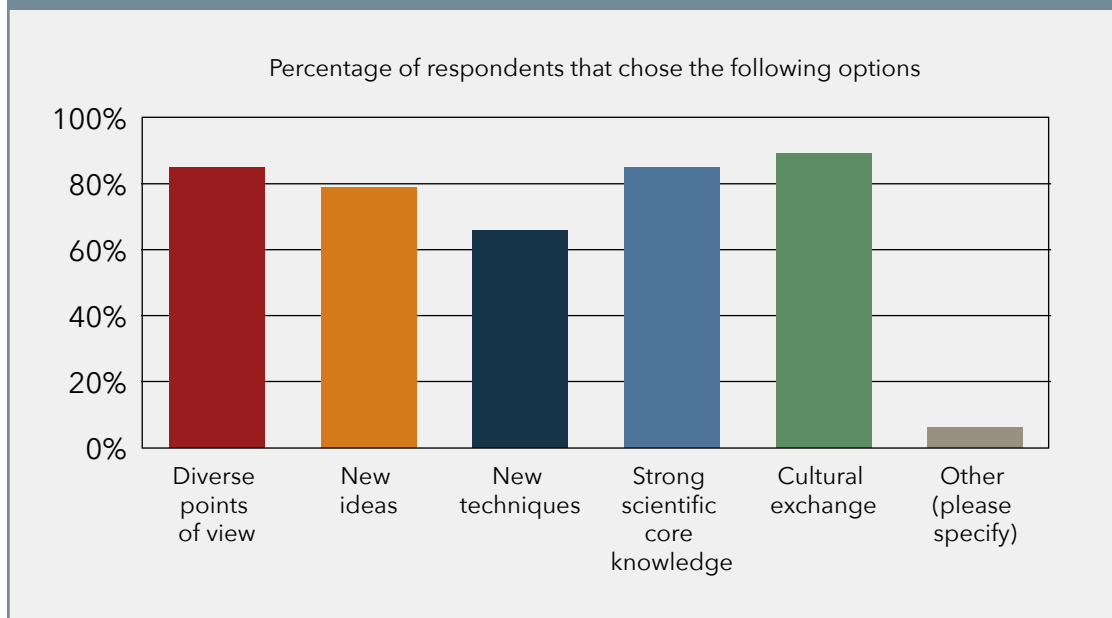
*Steven Albright, PhD
(2020 Graduate Yale Physics)*

Figure 4: How Often Do American Students and Early Career Scientists Interact Regularly with International Students and Scholars?



2020 APS Member Survey on US Visa and Immigration Policy

Figure 5: American Students and Early Career Scientists Recognize the Benefits that International Students and Scholars Bring to the US R&D Enterprise



2020 APS Member Survey on US Visa and Immigration Policy

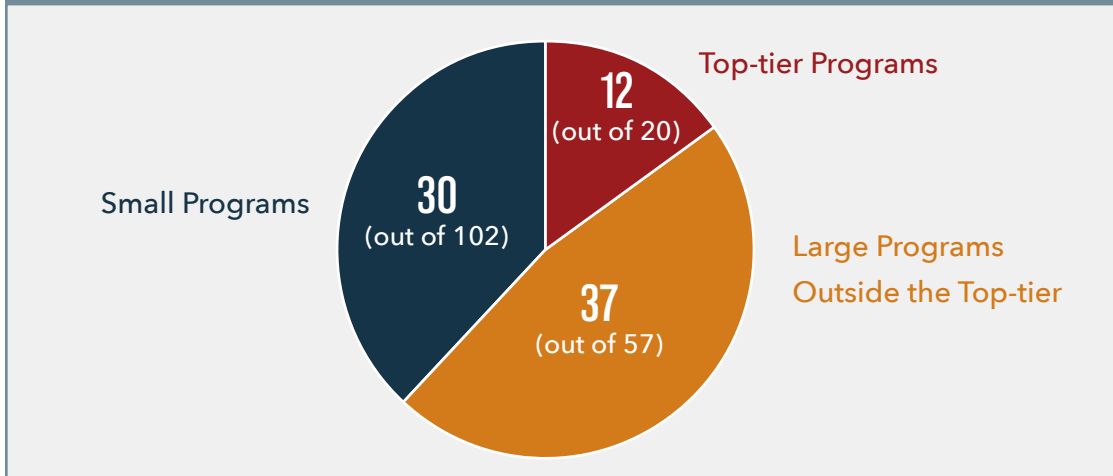
Troubling Declines & A Hole in the Pipeline

Despite evidence showing that international STEM workers benefit the US economy, domestic workers' jobs and salaries, [24] [23] [25] [22] and domestic scientists reporting the benefits of having international scholars be an integral part of the US R&D ecosystem, recent federal policies—both implemented and proposed—are discouraging international students and early career scientists from pursuing their careers in the United States. In physics, for example, a 2019 APS survey of physics department chairs at large US institutions showed an average 2-year decline of 22% in international applications to physics departments outside the top tier. [27]

APS recently completed a more comprehensive, follow-up survey in September 2020, which was sent to physics department chairs at all US institutions granting PhDs. Nearly 80 physics departments responded to the 2020 survey, with the responding departments accounting for approximately 53% of the total physics PhDs awarded in 2018. [28] In addition to application data, this survey also collected enrollment data for both international and domestic students.

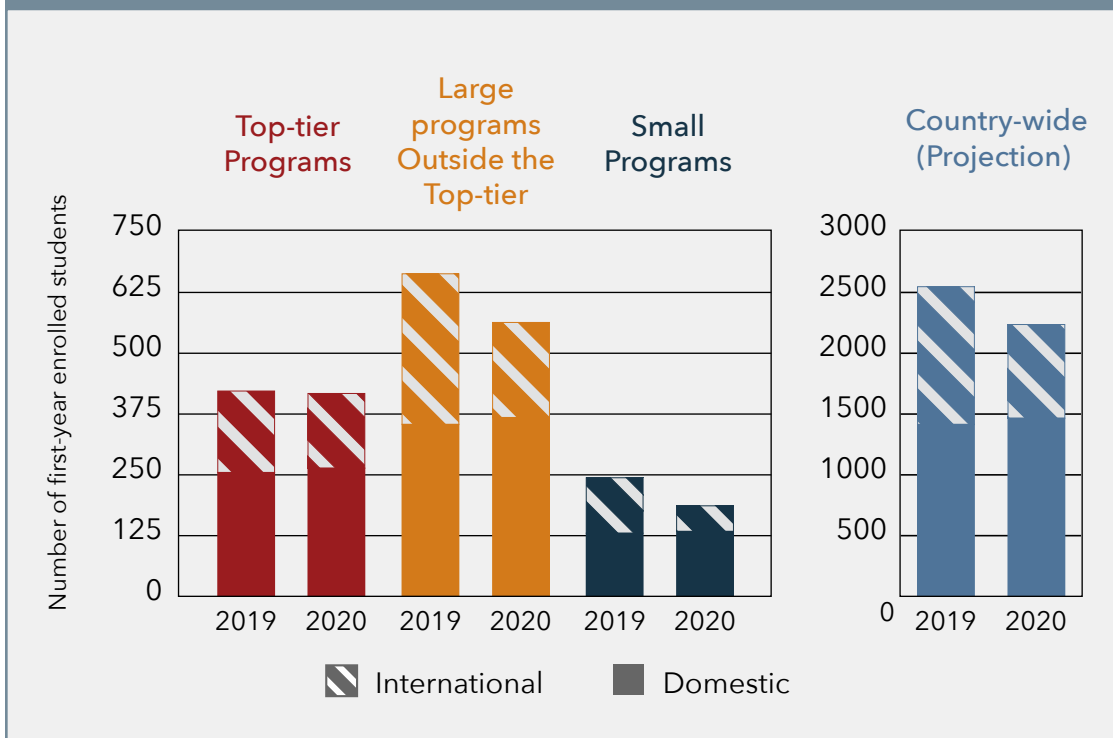
We sorted the survey results into three different categories: (1) top-tier departments, which were physics programs rated in the *US News & World Report* top 20 rankings; (2) departments outside the top 20 but that graduated 10 or more physics PhDs in 2018; and (3) small departments that graduated fewer than 10 physics PhDs in 2018. The survey revealed the following key results:

Figure 6: Departments Responding to APS 2020 Physics Department Chairs Survey Represent a Range of Institutions



APS 2020 Physics Department Chairs survey and <https://www.aip.org/statistics/reports/roster-physics-2018>

Figure 7: Survey Reveals Dramatic Decline in International Enrollment for First-Year Physics PhD Students



APS 2020 Physics Department Chairs survey

- Physics departments in all three categories saw their international enrollments drop in 2020 compared to 2019. For departments outside the top-tier, the average decline in enrollment was 40% (large departments) and 53% (small departments).
- We estimate there are approximately 360 fewer first-year, international PhD students in 2020 compared to 2019. This represents approximately 10% of the total first-year physics PhD students.
- Physics departments in all three categories, on average, saw increases in first-year enrollments of domestic PhD students due, in part, to US physics departments implementing better domestic recruitment strategies.
- The increase in domestic enrollments is not nearly enough to compensate for the loss of first-year, international PhD students. In total, we estimate a deficit of approximately 300 talented, diverse and innovative individuals in the physics PhD pipeline, which is a decrease of nearly 10% compared to 2019.

This dramatic decline in international physics PhD student enrollment—and first-year physics PhD student enrollment overall—creates an immediate hole in our STEM pipeline that has the potential to severely impact the US R&D ecosystem and could continue going forward unless action is taken. It disproportionately impacts programs outside the top-tier, with small departments seeing an average drop of 50% in their international first-year enrollment between 2019 and 2020.

Why We Are Losing Out

There are a number of plausible factors influencing this trend, including the perception and consequences of recent visa and immigration policy changes and the global crisis caused by COVID-19. To better understand the reasons behind the findings, APS conducted a survey of our international members—those members who are not US citizens or permanent residents—residing both inside and outside the United States.

More than 800 students and early career members from 65 countries participated in our survey. Respondents were divided into various groups, depending on their current location and whether or not they chose to study in the United States. The two primary groups of respondents are: (1) those who are currently studying or working in the United States and (2) those who chose to not come to the United States and pursue their PhD elsewhere.

More than 600 international members currently studying or working in the United States responded to our survey. Their message is clear—they face significant challenges to come

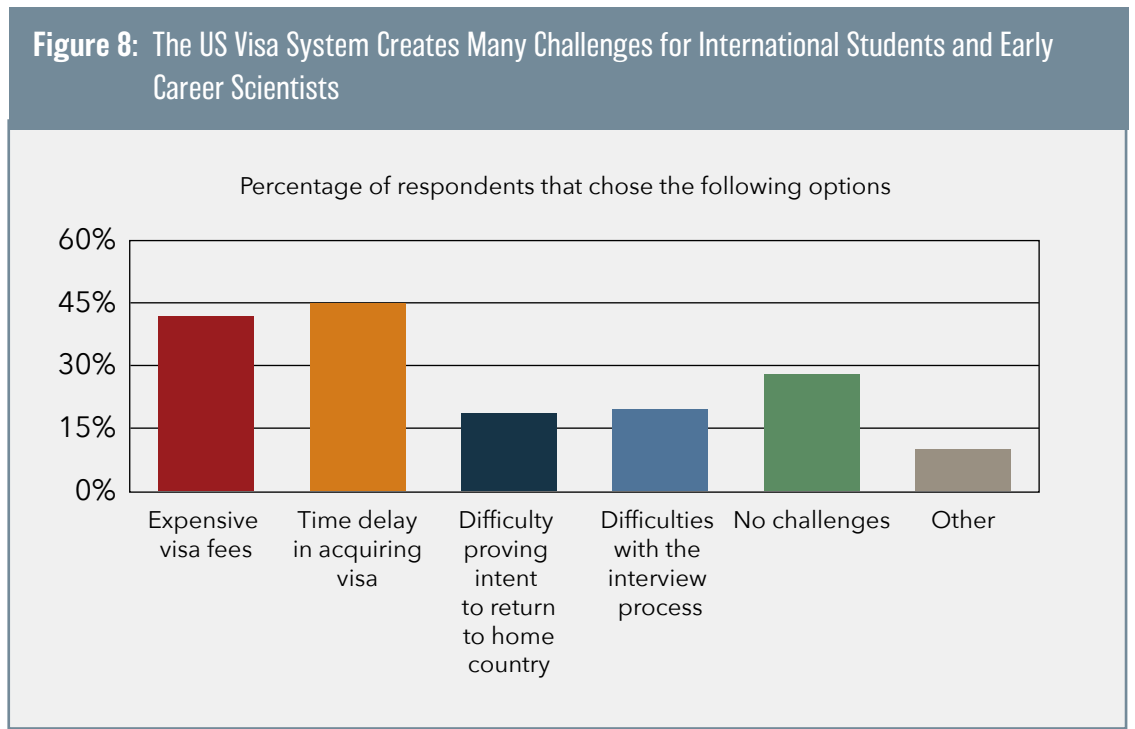
“It’s a slow-burning letdown year by year. It should not have been an uphill battle to maintain legal status in order to do top-notch research here. It now appears increasingly sad that this country doesn’t welcome people like us anymore.”

An international researcher in the US

here and these challenges contribute to making the United States a less attractive destination. More than 70% of the respondents reported having challenges obtaining a visa. The primary issue reported by respondents was a delay in the visa process, with **one in four respondents reporting a delay of at least two months and up to one year**. Such delays cause significant disruptions to their careers. Additional challenges include difficulty with the visa interview process (19%) and difficulty proving intent to return to their home country (19%).

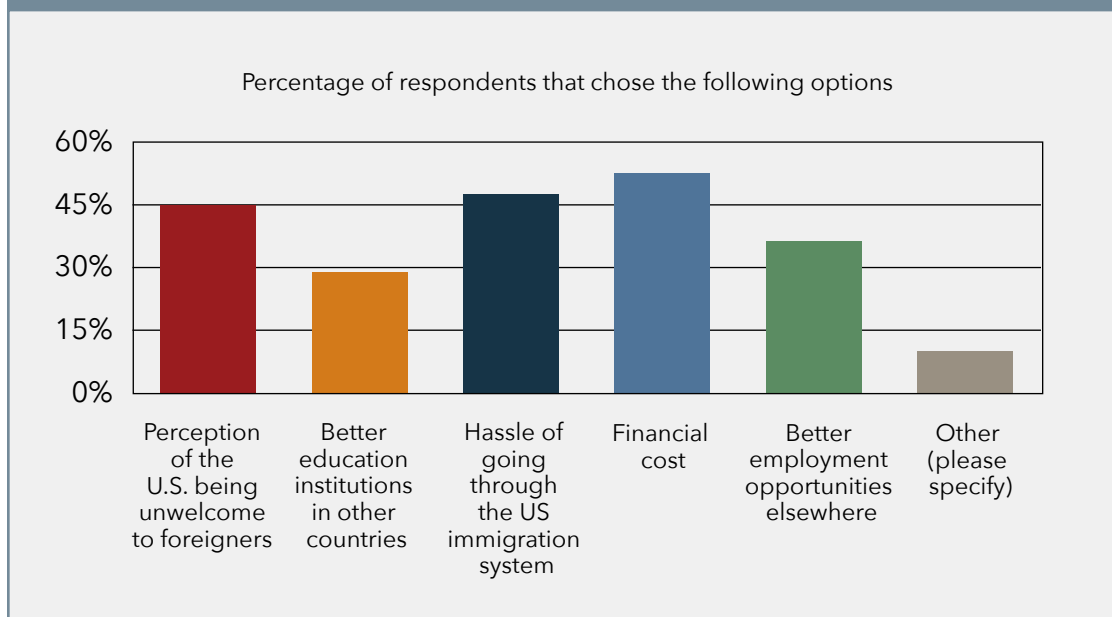
These survey respondents also provided nearly 150 additional “free response” comments, with more than half highlighting the stress and anxiety the US visa immigration system adds to their lives and about one quarter identifying the uncertainty and unexpected changes of US visa policy as a major challenge. Nearly one in six shared that they are actively pursuing career opportunities outside the United States as a direct consequence of their experience with the US visa system.

Of the approximately 130 respondents who chose not to attend a US institution for their PhD, more than 60% reported that they had considered the United States for their studies. However, more than 35% cited **better employment opportunities** elsewhere and approximately 30% identified **better educational opportunities** in other countries. Additionally, nearly half of respondents stated that the **perception that the United States is unwelcoming to foreigners** and the **hassle of going through the US immigration system** were reasons that they chose not to study/pursue a career here.



2020 APS Member Survey on US Visa and Immigration Policy

Figure 9: Why Do Some International Students and Scientists Choose Not to Pursue a PhD in the United States?



2020 APS Member Survey on US Visa and Immigration Policy

What We Can Do

In the United States, Optional Practical Training (OPT) and the H-1B visa are the primary programs that serve as the main routes for international early career scholars to pursue a professional career in the United States beyond their PhD. Approximately 70% of the international graduate students currently on F-1 visas who responded to our survey plan to apply for OPT, and more than 65% of respondents with F-1 or OPT status plan on applying for an H-1B visa.

Furthermore, our survey results clearly show that international students and early career scientists want to pursue their degrees in countries where they are able to stay and have a career after graduation. **Nearly 90% of respondents agree that they are “more likely to consider applying to graduate school or postdoc in a country that has a clear path for me to stay and work once I finish my degree or PhD.”**

Recruiting talented international students and scholars is essential to the future of America’s scientific enterprise. Today, the landscape is simply too competitive to ignore what the best and brightest are seeking—a nation that does not create unnecessary barriers for them to come and study there and, upon graduation, provides a clear path to stay and have a successful career. Our survey results show that the

direction for policymakers is clear—the United States needs a 21st century visa and immigration policy to attract and return top global talent for its 21st century workforce. Specifically, the following policy responses would have an immediate and substantial impact:

- Allow international students applying for an F-1 visa to indicate they would like to stay in the United States after graduation
- Provide international students who earn advanced STEM degrees from US institutions a clear path to a green card should they choose to stay and work in the United States after graduation

CONCLUSIONS

The United States cannot afford to continue to operate with a “business-as-usual” approach. Today, we do not properly prepare or appropriately support large segments of our domestic student population for STEM careers, and our outdated visa and immigration policies dissuade, rather than attract, international talent. Continuing the status quo simply will not suffice. Doing so will result in our nation losing its most critical R&D assets—talented human capital, both domestic and international, and the innovations they generate when working together.

The data and survey results provided above are clear evidence that timely actions by Congress and the Executive Branch are required to ensure we develop the 21st century workforce necessary to strengthen the US scientific enterprise and drive our innovation-driven economy. Specifically, policymakers need to develop and support policies that:

- address the urgent shortage in qualified STEM teachers, so that aspiring STEM-professionals have the opportunity to join the workforce of the industries of the future;
- eliminate hostile workplaces and pathways to all that want to contribute to innovation and a better society;
- build a research infrastructure that expands our research capacity and opportunities for all who want to participate, helping to ensure that taxpayer-funded federal R&D investments serve all Americans; and
- encourage the world’s best and brightest minds to come to the United States to study and stay to have a successful career here.

By following these policy responses, the United States will see an increase in the number of qualified STEM teachers and a larger, more-diverse STEM workforce that—when paired with robust and stable R&D funding—will ensure the United States continues to be a global leader in science, technology and innovation.

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