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Characterizing the Loss of Talent From the U.S. STEM Ecosystem

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S C I E N C E & T E C H N O L O G Y P O L I C Y I N S T I T U T E

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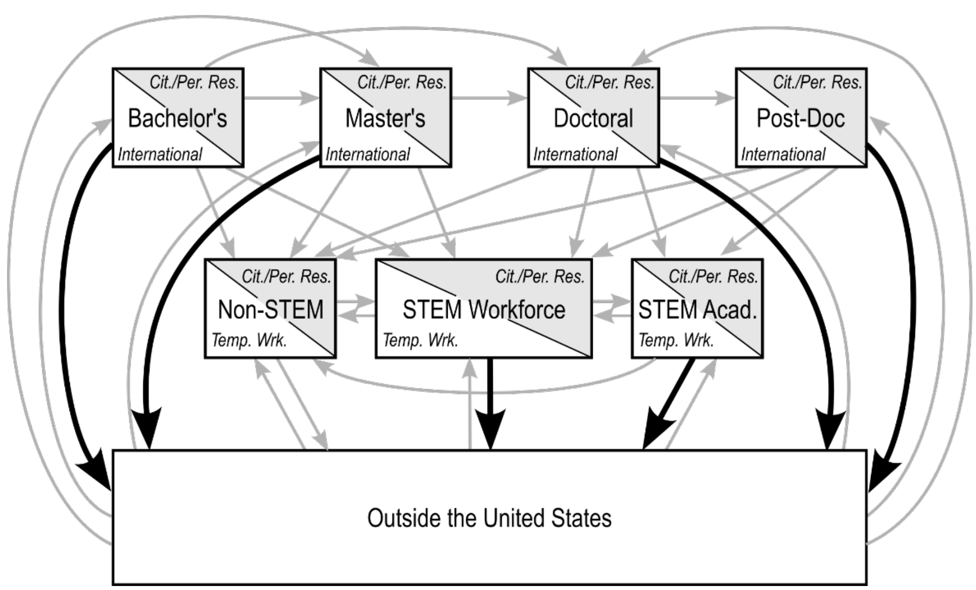
Executive Summary

The Office of Science and Technology Policy (OSTP) asked the Science and Technology Policy Institute (STPI) to support the Subcommittee on International Science and Technology Coordination by conducting research addressing the following recommendation in the Subcommittee's 2022 Report to Congress:

> *Conduct research to understand why STEM [science, technology, engineering, and math] talent leaves the United States or chooses to go to other countries, including examining the entire innovation pipeline to identify research, development, regulatory, statutory, capacity, and infrastructure challenges to STEM talent recruitment and retention.*

This research report develops a framework for understanding the loss of talent from the U.S. STEM ecosystem and uses publicly available information to estimate the magnitude of STEM talent flows in and out of the United States. It also reviews the published literature on the reasons that STEM talent comes to, stays, and leaves the United States.



Note: The top tier includes students and post-docs, divided into "Cit./Per. Res." (U.S. citizens and permanent residents) and "International" (i.e., noncitizens or permanent residents) categories. The middle tier includes workers, divided into "Cit./Per. Res." and "Temp. Wrk." (temporary foreign workers). The Non-STEM category accounts for talent flowing in and out of the STEM ecosystem within the United States. The bottom tier represents STEM talent outside the United States. Heavy, black arrows to "Outside the United States" indicate the loss of STEM talent. (Original figure prepared by STPI for this report.)

A Conceptual Model of Talent Flows through the U.S. STEM Ecosystem

A conceptual model of talent in the U.S. STEM ecosystem was created as a basis for organizing data on the magnitude of different educational and workforce pools of talent and the flows between them (see Figure). The model provides a means of integrating information on different parts of the STEM ecosystem from different sources and posing tractable hypotheses about the loss of STEM talent. It recognizes differences between domestic (U.S. citizens and permanent residents) and foreign talent (international students and temporary foreign workers) but does not attempt to distinguish flows of talent to and from different countries, which reflects the limits of available data. Flows between talent pools in the model were estimated using publicly available Federal data from a variety of agencies (National Science Foundation, Bureau of Labor Statistics, U.S. Citizenship and Immigration Services, and the U.S. Census Bureau) as well as information from published studies.

Minimal information was found on the magnitude of domestic STEM talent flows out of the United States, but the limited data available indicate that fewer Americans leave the country for STEM education or employment and more choose to return than comparably educated citizens of other nations.

Over 20% of both the U.S. STEM workforce and STEM graduates from U.S. colleges and universities are foreign born. Therefore, evaluating the magnitude and motivations of foreign STEM talent coming to and leaving from the United States is critical for understanding whether, where, and why loss occurs from the U.S. STEM ecosystem (see Table).

Estimated Gains and Losses of International Talent in the U.S. STEM Ecosystem

Students (based on degree completions in 2021)	
International students lost upon graduation (104,000 grads)	-27,000 to -29,000
Doctoral (14,000 grads)	-2000
Master’s (60,000 grads)	-7,000
Bachelor’s (30,000 grads)	-20,500
International students eventually lost from U.S. workforce based on number that obtain a temporary worker or other visa	-70,800
Post-Doctoral Scholars	
Long-term loss of U.S.-trained doctoral graduates	-2,800 to -3,500
Number of post-docs recruited from non-U.S. institutions	+2,500 to +3,500
Workers	
Total STEM workers obtaining H-1B visa	+82,000 to +112,000
Number of STEM workers not transitioning from international student status (net import gain)	+55,000 to +75,000
Number of STEM workers gaining employment-based lawful permanent resident status	+80,000 to +88,000

In 2021, 104,000 international STEM students graduated from U.S. institutions of higher education (30,000 bachelor's degrees, 60,000 masters' degrees, and 14,000 doctoral degrees). Of these, around 75,000 to 76,000 chose to stay to work in the United States immediately after completing their degree under the U.S. Optional Practical Training program (an initial stay rate of 72% to 73%). Over the longer term, data from U.S. Citizenship and Immigration Services suggest that approximately 38,000 international STEM students ultimately transition from a student visa to an employment-based or other visa, indicating that as many as 70,800 of the 104,000 international STEM graduates from U.S. universities in 2021 will eventually leave the country. However, the losses are not uniformly distributed across degrees: previously published research has found that long-term stay rates for international STEM doctoral students are around 75%.

Post-doctoral scholars make up a critical pool of highly educated and skilled STEM talent in the United States, 57% of whom are international. The proportion of international STEM post-docs in the United States is larger than the number of international STEM doctoral students reporting a commitment to stay in the country to take a post-doctoral position. The difference suggests that about 45% of international STEM post-docs in the United States were recruited from overseas institutions. This percentage translates to 2,500 to 3,500 post-docs annually, comparable to the long-term loss of U.S.-educated international STEM doctoral students. Data on the number of international post-doctoral scholars who eventually leave the United States were not found.

Workers coming to the United States must obtain a temporary work visa, the most common for high-skilled STEM workers being the H-1B category. The number of annual new H-1B approvals is capped at 85,000 (not including foreign workers at nonprofit academic and research institutions, who are exempt from the cap). Based on reported approvals, approximately 82,000 to 112,000 H-1B visas were awarded to workers in STEM occupations annually between 2012 and 2022. After subtracting the approximately 27,000 to 37,000 of these that represent transitions from various international student visa statuses, approximately 55,000 to 75,000 temporary foreign workers coming directly from other countries joined the U.S. STEM workforce each year (about 80% of them in computer-related occupations).

Temporary workers can remain in the United States on H-1B visa status for up to 6 years, after which they must transition to another visa category, be approved to enter the queue for permanent residency ("green card"), or leave the country. Data on the number of H-1B visa holders who leave the United States annually were not found. No publicly available count of employment-based permanent residency approvals going to individuals in STEM occupations was found. However, required labor certification approvals for green card applications include information on occupation, suggesting that 65% to 69% of applicants for employment-based permanent residency work in STEM fields (50% to 56% in computer-related occupations). Based on the number of approvals between 2012 and

2022, this suggests that between 80,000 and 88,000 new permanent residents per year work in STEM occupations.

The United States is an attractive destination for STEM students and workers. For students, the United States has the highest number of top-ranked universities in STEM, extensive educational and research infrastructure, and an education system that is accessible to international students. International students report the primary reason for coming to the United States is educational opportunity. In contrast, the primary reasons for leaving upon graduation are generally driven by family, personal, and cultural factors. Similarly, professional and economic opportunities attract high-skilled talent to the U.S. workforce. Although the duration and difficulty of obtaining a temporary work visa or permanent residency can be a deterrent from coming to and staying in the United States (for example, due to country quotas on green card approvals, Indian and Chinese applicants can wait years or even decades before they are approved), the most common reasons foreign individuals cite for leaving the U.S. STEM workforce are personal and cultural. In addition, programs designed to draw highly skilled talent to other countries attract much smaller numbers than flow into the United States.

The work presented here draws on a wide variety of publicly available Federal data sources and highlights where information is lacking. The academic disciplines and occupations that are included as STEM by different agencies are inconsistent, making comparisons across data sets highly provisional. In addition, different data sets often do not divide STEM talent by discipline, limiting the ability to document differences in recruitment and retention by STEM field. Lastly, the nationalities of students, workers, and visa holders are not always reported, limiting the ability to understand the flows of STEM talent to and from different countries. Accessible, consistent, and regular reporting of STEM talent data is needed to develop a clearer understanding of the flows of talent in and out of the U.S. STEM ecosystem.

Contents

1. Introduction

The International Science and Technology Cooperation Act of 2016,[1] part of the American Innovation and Competitiveness Act, instructs the Director of the Office of Science and Technology Policy (OSTP) to submit a biennial report on international science and technology cooperation efforts to the Senate Committee on Commerce, Science, and Transportation; the Senate Committee on Foreign Relations; the House Committee on Science, Space, and Technology; and the House Committee on Foreign Affairs. Reports were submitted in 2020 and 2022 by the National Science and Technology Council (NSTC) Subcommittee on International Science and Technology Coordination (ISTC).

NSTC's 2022 ISTC biennial report included 16 recommendations aimed at ensuring continued national excellence in those areas of international science and technology engagement where the United States is strong, and strengthening U.S. effectiveness in areas of opportunity. ISTC, with OSTP as co-chair, has agreed that the third biennial report should focus on assessing progress and opportunities to advance the 2022 recommendations. The second recommendation was to:

> *Conduct research to understand why STEM [science, technology, engineering, and math] talent leaves the United States or chooses to go to other countries, including examining the entire innovation pipeline to identify research, development, regulatory, statutory, capacity, and infrastructure challenges to STEM talent recruitment and retention.*

OSTP asked the Science and Technology Policy Institute (STPI) to support the ISTC Subcommittee in fulfilling this recommendation by synthesizing existing reports to identify gaps in understanding about the loss of STEM talent from the United States, using available Federal and non-Federal data sources to address identified research gaps, and proposing study designs for future work.

This report uses publicly available information to estimate the magnitude of talent flows in and out of the U.S. STEM ecosystem and reviews the current literature on the reasons that STEM talent comes to, stays, and leaves the United States. In addition, it develops a conceptual model for understanding the movement of talent through the U.S. STEM ecosystem with the aim of identifying gaps to be addressed in future research and data collection.

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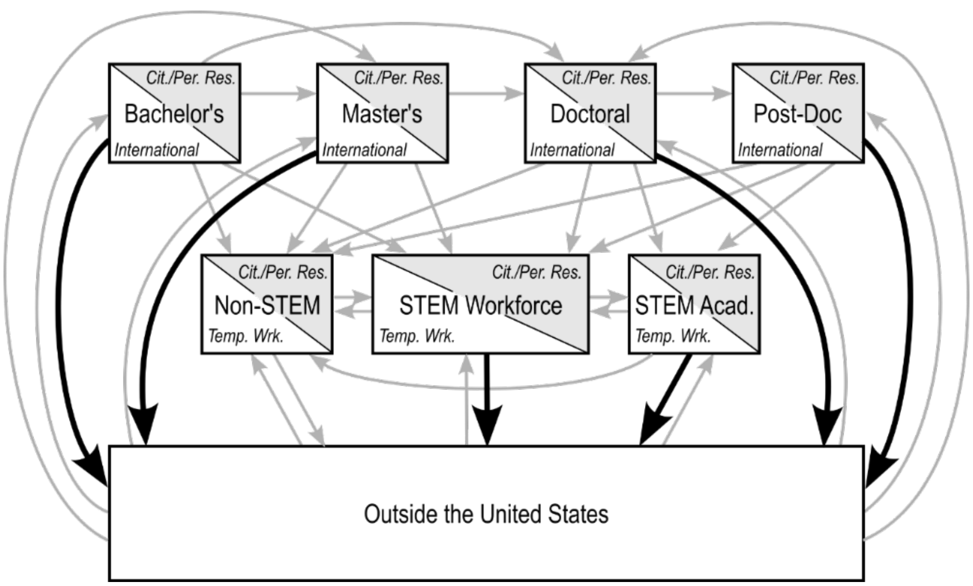
1 Public Law 114–329. https://www.congress.gov/114/plaws/publ329/PLAW-114publ329.pdf

2. Background

A. A Model of the U.S. STEM Talent Ecosystem

To understand the magnitude and motivations of STEM talent loss from the United States, STPI developed a conceptual model of the U.S. STEM ecosystem (i.e., the "STEM pipeline") linking distinct pools of STEM talent (Figure 1). This approach provides a means of using data on employment and education to estimate the size and turnover of STEM talent in the United States with an eye toward estimating the magnitude of loss from the U.S. STEM ecosystem (indicated by the heavy, black arrows in Figure 1). The model also provides a framework for identifying distinct populations of STEM talent—students versus workers, U.S.-born versus foreign-born, and citizens and permanent residents versus foreign temporary workers—that have different opportunities and motivations for staying in or leaving the United States. Acknowledging their differences is necessary for posing tractable hypotheses about the reasons for the loss of STEM talent and for developing solutions to alleviate it.



Note: The top tier includes students and post-docs, divided into "Cit./Per. Res." (U.S. citizens and permanent residents) and "International" (i.e., noncitizens or permanent residents) categories. The middle tier includes workers, divided into "Cit./Per. Res." and "Temp. Wrk." (temporary foreign workers). The Non-STEM category accounts for talent flowing in and out of the STEM ecosystem within the United States. The bottom tier represents STEM talent outside the United States. Heavy, black arrows to "Outside the United States" indicate the loss of STEM talent. (Original figure prepared by STPI for this report.)

Figure 1. A Conceptual Model of the U.S. STEM Ecosystem

The model is organized into three tiers: students and post-docs (top), workforce (middle), and outside the United States (bottom). Students and post-docs represent that part of the U.S. STEM ecosystem that is inherently transient—i.e., status in these categories is not intended to be long-term—and is primarily focused on education and development of skills. The workforce tier includes pools of talent defined by employment and is divided into academia, industry, and non-STEM. Academia and industry are differentiated because they are governed by different visa and employment rules for H-1B workers (the most significant category of foreign workers). Academia is intended to include STEM talent at government laboratories and nonprofit research institutions as well as universities due to similarities in the pools of talent they draw from and the rules governing H-1B workers (although there are important restrictions for non-citizens or permanent residents in the defense and intelligence research sectors). The non-STEM sector is included to acknowledge that talent can be lost from the STEM ecosystem without necessarily being lost from the country and that many highly skilled STEM workers do not have STEM degrees (i.e., they did not enter the STEM workforce from the student pools in the top tier).[2] The bottom tier represents STEM talent at any level of experience or skill outside the United States. It is the source of international students and foreign workers as well as a sink for those who leave the U.S. STEM ecosystem. The model does not attempt to distinguish flows of talent to and from individual nations due to limits on available data by country. Future research focusing on the differences in STEM talent flows to and from different countries is needed to fully understand the magnitude and motivations of STEM talent flows in and out of the United States.

This report attempts to use publicly available data to characterize the size of each pool in the model, the flows between them, and the flows in and out of the United States as a means of understanding where loss occurs from the U.S. STEM ecosystem. The size of different STEM talent pools and the flows between them are expected to vary over time. The most recent data from 2021 and 2022 are expected to reflect the lingering effects of the COVID-19 pandemic on educational, research, and workforce conditions. To provide context on potential distortions due to exceptional economic and societal events, most data presented in this report span an interval starting in 2012 (after the most extreme effects of the Great Recession) and ending in 2021 or 2022, the most recent year available in most of the data sources used.

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[2] Additional flows could be included in the conceptual model for workers with master's degrees or non-STEM backgrounds going to academia, but information on these flows was not found and it is assumed they are relatively small and do not play a major role in the loss of STEM talent from the United States. This assumption requires testing to be rigorously substantiated.

B. Defining STEM Talent

STEM typically encompasses a wide variety of academic and practical disciplines that involve the discovery of scientific knowledge and application of technical skills. However, there is no universally accepted definition of who counts as "STEM talent." Some sources include social science and clinical disciplines, whereas others do not. In addition, some sources use occupation as the basis for counting people as STEM talent, whereas others use their academic degree field. Lastly, some sources include the skilled technical workforce—i.e., those who do not have a bachelor's degree (NSB 2022)—in the accounting of STEM talent, whereas others do not.

The resulting differences in size estimates of the STEM talent pool in the United States can be substantial. For example, in 2021, the U.S. Bureau of Labor Statistics (BLS) counted 9.8 million STEM workers (6.6% of a total U.S. workforce of 147.9 million) in the United States (BLS 2022), whereas for the same year, the National Science Foundation (NSF) counted 34.9 million workers (23.8% of a total U.S. workforce of 146.4 million) employed in STEM occupations (NCSES 2023). BLS's definition is based on selected occupations in the 2018 Standard Occupational Classification, including workers engaged in science and engineering management; computer and mathematical occupations; architecture and engineering occupations; life scientists; physical scientists; science teachers; and those involved in the sale of scientific products. NSF's definition includes individuals employed in science and engineering occupations or those who have a bachelor's degree or higher in one of five broad categories: (1) computer and mathematics sciences; (2) biological, agricultural, and environmental life sciences; (3) physical sciences; (4) social sciences; and (5) engineering. The discrepancy in the size of the STEM workforce as reported by BLS and NSF reflects NSF's inclusion of (1) all those who earned a bachelor's or higher degree in science and engineering (not just those working in STEM occupations) and (2) social scientists as part of the STEM workforce, neither of which is counted in the BLS estimate. In addition, the disciplines that an agency includes under STEM can change from year to year, further complicating comparisons over time.

Estimates of the size of talent pools and flows in the U.S. STEM ecosystem presented in this report are based on data from a variety of Federal agencies. Data from different sources were selected to be as consistent as possible in terms of STEM disciplines, occupations, and degrees; the categories included from each data set are indicated in the data tables in the appendices of this report. The analyses presented here focus on STEM talent requiring a bachelor's or higher degree (or in the process of earning such a degree in the case of students) working in occupations involving research, development, or application of technical knowledge. Students and workers in the social sciences, clinical health fields, and STEM education were not generally included, except where they could not be parsed out of a given data set. This decision reflects (1) the exclusion of these fields from some of the source data sets and (2) an effort to improve consistency across data sources. The sensitivity of the results presented in this report to differences in the definition of STEM was not explored due to time constraints.

Although the analyses in this report represent an attempt at the best estimate possible using available public data, inconsistencies and gaps in the definition and accounting of STEM talent among different sources require all results to be treated as provisional. Improving the consistency and filling gaps in currently available data represent important directions for future research.

C. U.S. Visa Categories Most Relevant for STEM Talent[3]

Over 20% of the U.S. STEM workforce is foreign born (U.S. Census Bureau 2022), making U.S. immigration and naturalization policies an important constraint on the flow of STEM talent into and out of the United States. U.S. immigration and naturalization pathways are complex to navigate for both foreign STEM workers and their employers. Employment requirements, minimum length of stay, and numbers of visas issued vary depending on visa classification (Table 1).

Table 1. U.S. Visa Classifications Relevant to STEM Students and Workers

Nonimmigrant Visa		Immigrant Visa
Student	**Worker**	**Lawful Permanent Resident**
F-1: Academic student	H-1B: Temporary worker	EB-1: Individual of extraordinary ability
F-1: Optional Practical Training	O-1: Individual of extraordinary ability	EB-2: Professional with advanced degree and individual of exceptional ability
J-1: Exchange visitor – exchange students staying with a U.S. host family or boarding school; college or university students fulfilling degree objectives in their home country	J-1: Exchange visitor – professors and research scholars, short-term scholars, specialists, and trainees	EB-3: Skilled worker, professional, and other workers

Note: Other nonimmigrant and immigrant visa types are available; those listed are the most germane to STEM professionals.

3 This section is modified and updated from Appendix C of Balakrishnan et al. (2013).

U.S. immigration and naturalization is governed by the Immigration and Nationality Act of 1952,[4] which the Department of Homeland Security (DHS) implements and enforces through the U.S. Citizenship and Immigration Services (USCIS), Customs and Border Protection, and Immigration and Customs Enforcement, among other components.[5] The Department of State (DOS), through its embassies and consular offices, interprets visa laws and regulations and acts as a point of contact for visa applicants. It is also responsible for processing and issuing visas, both within and outside the United States. The Department of Labor (DOL) also plays a key role by processing labor certifications and labor condition applications (LCAs), which are required for employment-based permanent residents and certain temporary workers, respectively.[6]

1. Nonimmigrant Visas

Nonimmigrant visas are for foreign nationals who have been granted temporary entry into the United States for a specific purpose, including for academic or vocational study and temporary employment, and whose activities (e.g., employment, travel, and accompaniment by dependents) are prescribed by their visa classification. Some types of worker visas can require a hiring commitment by a sponsoring employer in the United States, and others may require an employer to establish that there are no able, qualified, and available U.S. workers for the position and that no U.S. job applicants have been rejected for valid, job-related reasons (USCIS 2024).

The F-1 visa classification is for individuals enrolled as full-time students at a DHS-approved academic institution or language training program with the intention of obtaining a degree, diploma, or certificate. These students must maintain a residence abroad and may not pursue permanent residency status while maintaining their F-1 visas. F-1 visa applicants are required to document their intent to depart the United States upon completion of their course of study as part of the application process (DOS Bureau of Consular Affairs n.d.). There are no caps on the number of F-1 admissions each year.

F-1 visa holders are eligible for Optional Practical Training (OPT), a program managed by DHS that allows international students to receive up to 12 months of employment authorization before or after completing their academic studies (USCIS

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4 See 8 U.S.C. §§1 et seq. for more information. https://uscode.house.gov/view.xhtml;jsessionid=BC555D67E91F56A12E30C5499E2AE04C?req=granuleid%3AUSC-1994 title8&saved=%7CY2hpbGQgcG9ybm9ncmFwaHk%3D%7CdHJlZXNvcnQ%3D%7C%7C0%7Cfalse%7Cnull&edition=prelim

5 Implementing regulations are located in title 8 of the Code of Federal Regulations. https://www.ecfr.gov/current/title-8

6 Labor certifications for permanent residence verify there are insufficient qualified and willing U.S. workers to fill the position and that hiring a foreign worker will not adversely affect the wages and working conditions of similarly employed U.S. workers.

2023a). Students earning U.S. degrees in designated STEM fields can apply for an additional 24-month extension of their OPT employment authorization (USCIS 2023b). (The STEM extension was initially introduced in 2008 for 17 months and subsequently extended to 24 months in 2016.)

Foreign STEM workers either abroad or already in the United States on a temporary visa can be hired by U.S. employers. The pertinent nonimmigrant classifications are H-1B, O-1, and J-1 Trainee visas.[7] The H-1B nonimmigrant classification is intended primarily for individuals who perform services in specialty occupations. These individuals must have at least a bachelor's or equivalent degree and be sponsored by an employer for a job with complex and specialized needs that only an individual with a degree in a related field can fill. There is an annual fiscal year cap of 65,000 H-1B visas, but there are several statutory exemptions. An additional 20,000 approvals can be awarded each fiscal year for individuals with a U.S. master's or higher degree. In addition, there is no cap on H-1B approvals for employment at institutions of higher education (and related or affiliated nonprofit entities), nonprofit research organizations, and government research organizations.[8]

H-1B approvals are granted on the condition of employment with a specific employer, who must submit a DOL-approved LCA form to USCIS. The form certifies that the employer will comply with certain wage and working condition requirements and that the employment of the H-1B nonimmigrant will not adversely affect the wages of similarly employed U.S. workers. A person in H-1B status may simultaneously maintain H-1B nonimmigrant status and pursue lawful permanent resident (LPR) status. H-1B status is normally limited to 6 years, but extensions are possible for individuals who are waiting for a permanent immigrant visa number to become available or if they are subject to lengthy adjudication delays in their application for LPR status.

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[7] In the U.S. immigration system, post-doctoral researchers are treated as workers; they typically work in the United States under H-1B and J-1 Trainee visas, although those doctoral graduates who completed their degree at a U.S. institution can also work as in post-doctoral positions while on F-1 OPT status.

[8] Several countries have pathways for temporary employment separate from standard H-1B caps. The H-1B1 program allows employers to temporarily employ foreign workers from Chile and Singapore in the U.S. on a nonimmigrant basis in specialty occupations under the provisions of free trade agreements between the United States and each country. Current laws limit the annual number of qualifying foreign workers who may be issued an H-1B1 visa to 1,400 from Chile and 5,400 from Singapore; in 2022, a total of 582 specialty H-1B1 worker visas were approved (USCIS 2023c). Professionals from Canada and Mexico, including but not limited to STEM workers, can be admitted under the TN visa in accordance with the United States-Mexico-Canada Agreement. In 2022, the total number of TN professionals admitted to the United States under this classification was 716 (USCIS 2023c). Lastly, E-3 visas allow employers to temporarily hire up to 10,500 foreign workers from Australia in the U.S. on a nonimmigrant basis in specialty occupations; in 2022, the number of E-3 visas was less than 327 (USCIS 2023c). In total, these pathways represent less than 1 percent of the number of new H-1B approvals awarded each year and will not be further considered in this report.

The O-1 nonimmigrant visa is for individuals with extraordinary ability in sciences, arts, education, business, or athletics and extraordinary achievement in motion picture or TV production to perform specific events or activities in the United States; the O-1A classification, which includes individuals with extraordinary ability in the sciences, is most relevant to STEM workers. These individuals must have demonstrated sustained national or international acclaim and risen to the top of their fields. Employers must sponsor individuals for an O-1 visa classification, but the application does not require an LCA. O-1 nonimmigrants can enter the United States for up to 3 years initially, with indefinite extensions available to complete the initial event or activity in increments of up to 1 year.

The J-1 Exchange Visitor Program is a nonimmigrant visa classification overseen by DOS that is intended to foster global understanding through educational and cultural exchanges. DOS has a designated list of sponsors that are certified to participate in the J-1 program, and exchange visitors may engage only in the activities stated on their Certificate of Eligibility for Exchange Visitor Status. A variety of J-1 classifications are relevant to the U.S. STEM ecosystem (Monger and Yankay 2012).

The J-1 College and University Student classification allows foreign students the opportunity to study at American degree-granting post-secondary accredited academic institutions or participate in student internship programs that will fulfill the educational objectives of the degree programs in their home countries. Maximum duration is 24 months.

The J-1 Professor and Research Scholar classification provides foreign professors and research scholars the opportunity to engage in research, teaching, and lecturing in the United States for a maximum of 5 years. (This stay may be extended to a maximum of 5 additional years for individuals engaged in research under the direct sponsorship of a federally funded research and development center or U.S. Federal laboratory.)

The J-1 Specialist classification is for experts in fields of specialized knowledge or skill who are promoting the interchange of knowledge and skills with American specialist peers for a maximum of 1 year.

The J-1 Trainee classification is for individuals with degrees or professional certificates from a foreign post-secondary institution and 1 year of work experience abroad in their occupational fields or for individuals with 5 years of work experience abroad in their fields. J-1 Trainees must participate in a sponsor-guided work-based program in their academic or occupational fields; they may stay for a maximum of 18 months.

2. Immigrant Visas

Immigrant visas grant a recipient a "green card" or LPR status, which permits holders to live and work permanently anywhere in the United States, own property, and attend public schools, colleges, and universities. LPRs may also join certain branches of the

Armed Forces and apply to become U.S. citizens if they meet certain eligibility requirements (Monger and Yankay 2012).

LPR status is divided into a number of categories, including family-sponsored preference, employment-based preference, and diversity immigrants. The employment-based (EB) preference limit is equal to 140,000 plus any unused visas in the family-sponsored preferences from the previous year. The EB immigrant visa has five preference categories, of which the first three are most relevant to high-skilled STEM talent. Preference categories EB-1 through EB-3 are each allocated 28.6% of annual visas (equivalent to 40,040 visas), while categories EB-4 and EB-5 each receive 7.1 percent (equivalent to 9,940 visas). EB visas are subject to per-country and dependent limits defined as the maximum number of family-sponsored and employment-based preference visas that can be issued to citizens of any country in a fiscal year. The per-country limit is equal to 7% (i.e., 25,620), and the dependent limit is set at 2% (i.e., 7,320) of the total annual number of family-sponsored and employment preference limits (DOS Bureau of Consular Affairs 2023).

The EB-1 classification is for individuals of extraordinary ability, outstanding professors and researchers, and multinational managers or executives. Among other criteria, EB-1 applicants must demonstrate evidence of original scientific, scholarly, artistic, athletic, or business-related contributions of major significance to their field; receipt of lesser nationally or internationally recognized prizes or awards for excellence; and/or evidence of published material about the applicant in professional or major trade publications or other major media.

The EB-2 classification is for professionals falling into two categories: individuals with advanced degrees and individuals of exceptional ability. Those in the advanced degree category must have a degree equivalent to bachelor's or higher and at least 5 years of progressive work experience in their area of study. Individuals in the exceptional ability category must show a degree of expertise significantly above that ordinarily encountered in the field. EB-2 must be accompanied by a labor certification approval.

The EB-3 classification accommodates skilled workers, professionals (without advanced degrees), and other workers. "Professionals" are individuals whose jobs require at least a U.S. baccalaureate degree or a foreign equivalent and who are members of the professions. A labor certification approval and a permanent, full-time job offer are required as part of the EB-3 application.

The EB-4 classification applies to certain special classes of immigrants (e.g., ministers, religious workers, and employees of the U.S. Government abroad), and the EB-5 classification covers immigrants involved in employment creation or "investors."

3. Naturalization and Citizenship

Naturalization is the mechanism established by the Immigration and Nationality Act to grant U.S. citizenship to foreign citizens. Most legal permanent residents who are at least 18 years of age are eligible to apply for naturalized citizenship after meeting certain requirements, which generally include 5 years of lawful permanent residency in the United States (3 years for those married to a U.S. citizen) and successful completion of English language, civics, and history tests.

3. The Student Pool of STEM Talent

Much of the analysis and discussion in this chapter will focus on international students (i.e., noncitizens or permanent residents coming from outside the United States specifically for education) rather than domestic students (i.e., U.S. citizens and permanent residents), because international students must leave the country upon completing their degree unless they change their student visa status or choose to participate in post-graduation OPT. In contrast, although domestic STEM students may exit the STEM ecosystem after graduation, they are not required to leave the United States when they finish their studies (text-box: U.S. Students Overseas).

U.S. Students Overseas

Many fewer U.S. students choose to pursue degrees in other countries than the number of international students coming to the United States. In 2022, 80,516 American students were reported to be studying outside the United States, two-thirds of whom were in Canada, Mexico, and the United Kingdom (Project Atlas 2022). Of those students whose field of study was reported, 36% of U.S. students were pursuing degrees in physical and life sciences or in engineering, mathematics, and computer sciences. For comparison, the number of international students enrolled in U.S. universities in 2021 was 764,000 and the total number of students enrolled at U.S. universities and colleges was 20.3 million (Institute for International Education 2022). Although return rates for U.S. students earning degrees at foreign institutions are not known, Franzoni et al. (2012) found that over 70% of U.S. scientists studying or working outside the United States planned to return.

Attracting and retaining international students is central to building the Nation's high-skilled STEM workforce. In contrast to immigrants directly entering the U.S. workforce, international students have had time to acculturate, gain language fluency, and obtain qualifications that do not require recognition of foreign degrees or professional certifications (Hawthorne 2014; Skeldon 2014).

A. Why International Students Come to the United States

Of the more than 6.4 million students studying anywhere in the world outside their home country in 2020, the largest proportion—15%—came to the United States (Project Atlas, 2022). In 2022, of 948,519 international students in the United States, 304,020 were enrolled in bachelor's degree programs and 385,097 were enrolled in graduate degree programs (the remainder were enrolled in associate's, non-degree, or OPT programs). Of these, 200,301 were working to earn a degree in math or computer science, 78,712 in physical or life science, and 188,194 in engineering (OpenDoors 2023).

In 2023, the Organisation for Economic Co-operation and Development (OECD) ranked the United States as the most attractive country for international university students based on the number of top-ranked universities, accessibility of education for non-citizens or permanent residents, educational and research infrastructure, and broad-based quality of life (Dumont and Andersson 2023).

Of the top 25 institutions of higher education in the Times Higher Education World University Rankings (2023), 16 are in the United States (Appendix A). Of the top 25 institutions in various STEM fields, the United States had 13 in computer science, 14 in engineering, 15 in life sciences, and 13 in physical sciences. The quality of U.S. educational institutions is one of the top reasons reported by international students for coming to study in the United States (Han et al. 2015; Stephan et al. 2015; Esaki-Smith 2022).

In addition to the perceived quality of its institutions of higher education, the United States also has the largest selection: approximately 200 research universities, over 700 additional universities offering graduate degrees, and approximately 900 4-year colleges offering bachelor's degrees (Teitelbaum 2014). In contrast, the United Kingdom, France, Germany, and Canada—some of the strongest global competitors for international student talent—together have only approximately 200 degree-granting institutions (Teitelbaum 2014).

The United States offers easier access for international students to higher education than most other countries. The mixture of public and private support for the U.S. higher education system allows universities and colleges to act relatively autonomously with respect to the admission of students from overseas (Teitelbaum 2014). In contrast, higher education in most other countries is primarily supported by national, provincial, or local governments, putting a priority on educating their own citizens rather than international students (Teitelbaum 2014).

International students are an important source of revenue for U.S. universities (Stephan et al. 2015; Shih 2017; Hawthorne 2018). Whereas domestic students have access to in-state tuition at public universities and many institutional scholarships at private colleges, international students often pay full tuition as non-U.S. residents. As a result, the United States is a global leader in "export education" (Hawthorne 2018)—i.e., training foreign students without the intention of long-term immigration after they graduate. According to NAFSA (2020), international education is the fifth-largest U.S. service sector export, generating $41 billion dollars in value and supporting 458,000 jobs in the 2018–2019 academic year.

At the graduate level, particularly for those pursuing doctoral degrees, the U.S. system of "joint production" of high-level research and graduate education is another important opportunity for international students that differs from many other countries (Teitelbaum 2014). In most other countries, publicly supported research is conducted at specialized institutes separate from universities, and graduate students are supported through fellowships or stipends awarded to the individual rather than through grants awarded to institutions or researchers. In contrast, the United States supports a substantial portion of graduate education in the STEM disciplines through research funding to universities. This structure gives principal investigators the ability to spend research dollars to support students, including international students who would otherwise not qualify for government fellowships (e.g., NSF Graduate Fellowships, which are restricted to U.S. citizens, nationals, and permanent residents[9]). Access to different funding sources is reflected in how domestic and international doctoral students are supported in the United States: in 2021, 51.7% of international science and engineering doctoral students were supported on research assistantships or traineeships, whereas only 33.8% of U.S. citizens and permanent residents were (Table 4-1, NSF SED 2021).

Although the United States has been a generally attractive destination for STEM education, changes to the perception of the country's friendliness to immigrants and foreigners can influence where international students choose to go for a degree. In particular, recent policies placing restrictions on students and researchers from China (e.g., Presidential Proclamation 10043[10]) coincide with a decrease in the number of Chinese students enrolled in U.S. academic programs (8.6% decline between 2021 and 2022; Chen 2023) and the number of students in China expressing an interest in pursuing studies in the United States versus other countries (Ma 2023).

B. Why International Students Leave the United States

The attractiveness of the United States for international students primarily reflects the educational opportunities and institutional structure of the U.S. research and higher education system. Connan (2022) reports that 73% of international students indicated a desire to stay in the United States immediately upon graduation, given the opportunity, and 38% would be interested in staying 4 or more years after graduation. Esaki-Smith (2022) found that 41% of surveyed international students expressed interest in working the United States for a short while before leaving and 31% expressed interest in working in the United States for an indeterminate duration. However, international students are an "educational

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9 NSF Graduate Research Fellowship Program. 2023. *What is GRFP?* https://www.nsfgrfp.org/

10 Executive Office of the President. May 29, 2020. *Proclamation 10043: Suspension of Entry as Nonimmigrants of Certain Students and Researchers From the People's Republic of China.* https://www.federalregister.gov/documents/2020/06/04/2020-12217/suspension-of-entry-as-nonimmigrants-of-certain-students-and-researchers-from-the-peoples-republic

export," so many leave the United States after they complete their degrees. A consistent result of studies investigating the reasons why international students leave the United States indicates motivations that are more personal, cultural, and individual, in contrast to the professional and economic opportunities that motivate them to stay.

Based on structured group interviews with 31 international students (undergraduate and graduate students from multiple countries, 11 of whom were in STEM disciplines) at the University of Minnesota, Alberts and Hazen (2005) found the main reasons for coming to the United States were availability of funding for graduate students and the overall quality of graduate programs. Students appreciated the more open and less hierarchical academic culture of the United States relative to their home countries, and reported that a U.S. degree could lead to better job opportunities back home. More than half did not come to the United States with the intention to stay, but a majority were interested in staying to work for a few years. The reasons to come and to stay were dominated by professional considerations, such as better access to research facilities (for those interested in pursuing a career path in research or academia) and better pay and job opportunities than in their home countries. In contrast to the reasons that attracted international students to come to the United States, Alberts and Hazen (2005) found that the factors that led them to return home primarily concerned family and culture. Many students expressed a sense of displacement in the United States that is common among immigrants—i.e., the feeling of not being "fully American."

Han et al. (2015) conducted a survey of 166 international graduate students (not restricted to STEM) from 32 countries at the University of California-Santa Barbara to assess their intentions and motivations to return to their home countries. Students reported that they came to this country for the high-quality education and to enhance their future career opportunities. The students most likely to report an intention to stay were those driven primarily by career considerations. In contrast, for those intending to leave the United States, family was the most common reason. A small number of students also mentioned the complexity and uncertainty of U.S. immigration and naturalization policy as a deterrent to staying in the United States after graduating.

Other studies have sought to identify factors that correlate with the likelihood that an international student stays in or leaves the United States. Kim et al. (2011) examined long-term trends by examining three cohorts of respondents to NSF's Survey of Earned Doctorates[11] (SED): 1984–1990, 1991–2000, and 2001–2005. They found that overall rates

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[11] The Survey of Earned Doctorates is an annual census of all individuals receiving a research doctorate from an accredited U.S. institution in a given academic year. It is sponsored by NSF NCSES and by the National Institutes of Health, Department of Education, and National Endowment for the Humanities. The SED collects information on the doctoral recipient's educational history, demographic characteristics, and postgraduation plans. Results are used to assess characteristics of the doctoral

of return decreased from 51% in the 1980s to 34% in the early 2000s. They also found that stay rates were higher for graduates in STEM than the social sciences or education. Other factors that increased the likelihood that a graduate would stay included lack of employment opportunities in their home country, college-educated parents, and having earned a bachelor's degree in the United States.

Brentschneider and Dei (2017) used data from NSF's Survey of Doctoral Recipients[12] (SDR) to look for factors that correlate with the likelihood of international graduates staying or leaving the United States. Factors that increased the likelihood of staying included the difference in median salaries between the United States and their home country, as well as the tightness of the labor market in their home country. Having a bachelor's or master's degree from their home country increased the likelihood of return after finishing a doctorate in the United States.

Wadhwa et al. (2009) surveyed 1,203 Chinese and Indian immigrants who worked or received their education in the United States and then returned to their home countries. By far, the most common reasons for coming to the United States were professional and educational development. In addition, most respondents were not influenced in their decision to come to the United States by the availability of jobs in their home country. The major factors in the decision to return home were family ties, quality of life, and a demand for their skills. Remarkably, 76% of respondents reported that restrictive U.S. immigration policies did not contribute to their decision to leave the United States, and 34% of Chinese respondents and 27% of Indian respondents held green cards—i.e., had LPR status, indicating minimal barriers to remaining in the United States. In addition, although around 47% of respondents who had left said they were unlikely to return to the United States, more than 25% reported that they were likely or very likely to return.

Overall, international students report coming to the United States for educational opportunities and staying for professional and employment opportunities (although the intention of seeking an education in the United States may have been motivated by eventually seeking the opportunity to work in or migrate to this country). Those who return to their home countries report being driven more by personal motives rooted in family and culture, although good work opportunities at home were also cited in some cases as attractive. Although the complex and restrictive U.S. immigration and naturalization

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population and trends in doctoral education and degrees. https://ncses.nsf.gov/surveys/earned-doctorates/2022

[12] The Survey of Doctoral Recipients includes demographic, education, and career history information from individuals with a U.S. research doctoral degree in a science, engineering, or health field sponsored by NSF's NCSES and the National Institutes of Health. It provides information about the educational and occupational achievements and career movement of U.S.-trained doctoral scientists and engineers in the United States and abroad. https://ncses.nsf.gov/surveys/doctorate-recipients/2021

system was cited by some as a deterrent to coming to the United States, it was largely mentioned anecdotally and as a secondary factor for leaving.

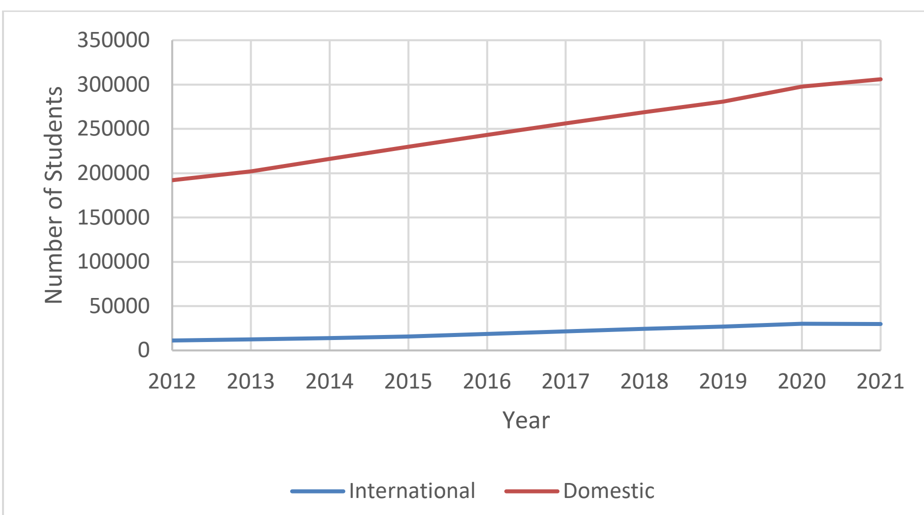
C. Estimating the Flows of STEM Student Talent

The number of domestic and international students in STEM disciplines graduating each year defines a critical influx of talent into the U.S. STEM workforce. Comparing graduation rates with the number of international students who subsequently leave provides a means of assessing the loss of international STEM talent educated in the United States.

Being a student is an inherently transient status, so the pools of student talent in the U.S. STEM ecosystem (Figure 1) experience a high degree of turnover. For international students, coming to the United States to study provides a conduit to enter the U.S. STEM ecosystem and is an important means of future recruitment into the U.S. STEM workforce. The three student pools—bachelor's, master's, and doctoral degrees—have been separated because each represents a different level of education, training, and skill, and each represents a population with potentially different intentions and motivations to stay in the United States after they finish their studies.

1. Bachelor's Degrees

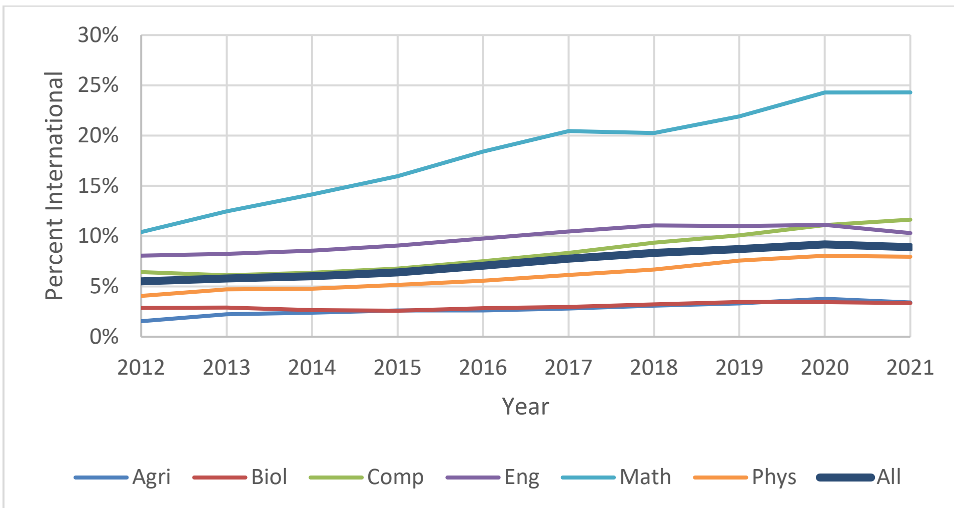
The total number of bachelor's degrees awarded in STEM disciplines in the United States has steadily increased over the past decade from 203,235 in 2012 to 335,900 in 2021 (Appendix B). This trend is true for degrees awarded to U.S. citizens or permanent residents ("domestic students") and nonresident aliens ("international students"; 11,194 in 2012 to 29,964 in 2021; Figure 2).



Note: Data available in Appendix Tables B-1 and B-2.

Figure 2. Number of International (blue) and Domestic (red) Students Receiving a Bachelor's Degree in a STEM Discipline 2012–2021

Over the same period, the proportion of STEM bachelor's degrees awarded to international students increased from 5.5% to 8.9% (Figure 3). However, the proportion of international students receiving a bachelor's degree varies both by STEM discipline, from just 3.3% in the biological and biomedical sciences to 24.3% in mathematics and statistics in 2021 (Figure 3), and over time. The most dramatic increases in international student participation between 2012 and 2021 were in computer and information sciences (from 6.4% to 11.6%) and mathematics and statistics (from 10.4% to 24.3%). In contrast, biological and biomedical sciences as well as engineering show slight decreases in international student participation, with peaks around 2018 and 2019.



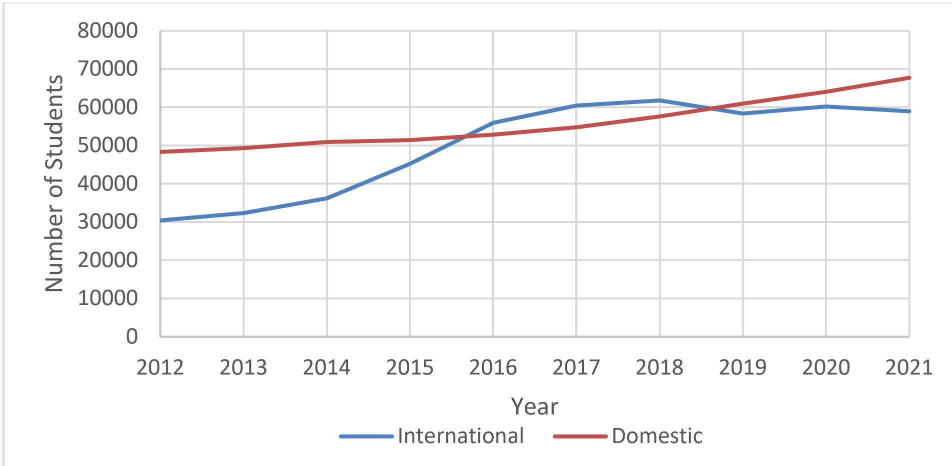
Notes: Agri = agriculture and related sciences; Biol = biological and biomedical sciences; Comp = computer and information sciences; Eng = engineering; Math = mathematics and statistics; Phys = physical sciences (including geosciences); All = all STEM.

Data available in Appendix Table B-3.

Figure 3. International Percentage of Bachelor's Degree Graduates in STEM Disciplines 2012–2021

2. Master's Degrees

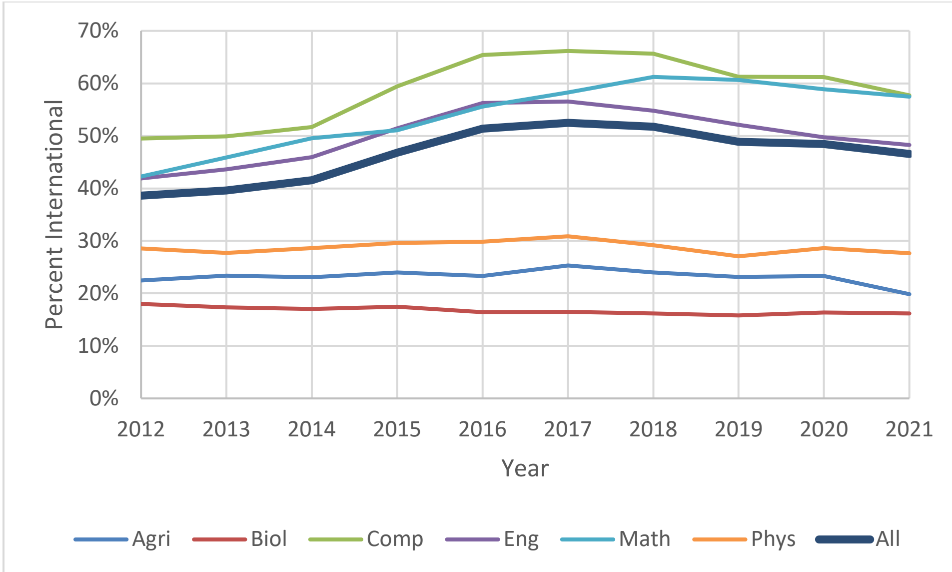
The total number of students receiving master's degrees in a STEM discipline in the United States grew from 78,725 in 2012 to 126,631 in 2021 (Appendix B). However, the trajectory of change differs dramatically between international and domestic students. For domestic students, it increased at an accelerating rate through the study period, but for international students it shows a rapid rise from 2012 to 2016 followed by relatively constant numbers through 2021 (Figure 4).



Note: Data available in Appendix Tables B-4 and B-5.

Figure 4. Number of International (blue) and Domestic (red) Students Receiving a STEM Master's Degree between 2012 and 2021

The proportion of master's degrees in STEM awarded to international students varies by discipline (Figure 5). Agriculture and related sciences, biological and biomedical sciences, and physical sciences have the lowest proportion of master's degrees awarded to international students (20% to 30%); between 2012 and 2021, the proportion of international students in these fields stayed relatively steady or decreased slightly. In contrast, mathematics and statistics, physical sciences, and engineering range from 40% to 50% of master's degrees awarded to international students in 2012 to peaks between 55% and 65% from 2016 to 2018 before decreasing to 50% to 60% in 2021. It is the variation in these three STEM disciplines that drives the overall pattern of increase in the number of international students earning master's degrees in STEM from 2012 to 2021 (Figure 4).



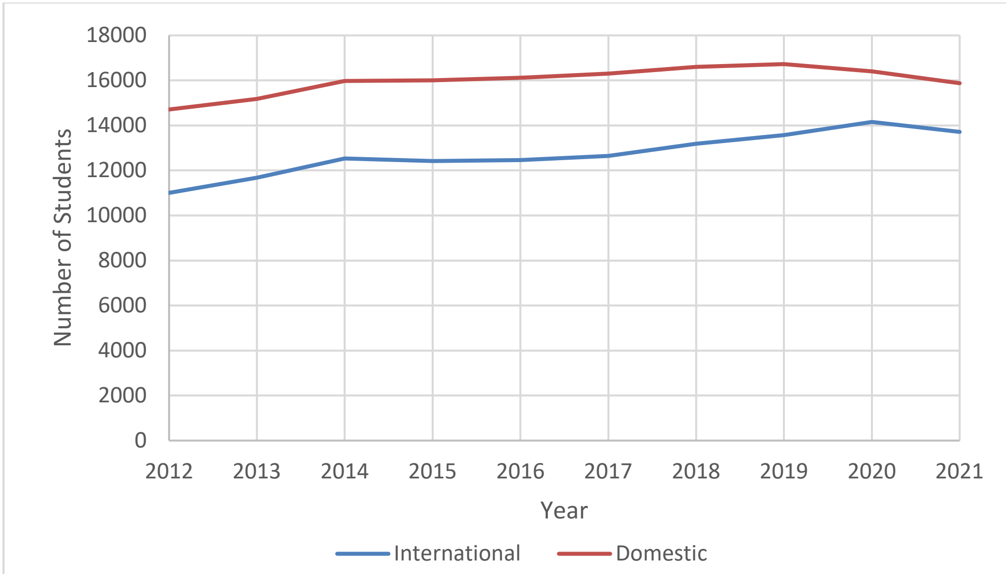
Notes: Agri = agriculture and related sciences; Biol = biological and biomedical sciences; Comp = computer and information sciences; Eng = engineering; Math = mathematics and statistics; Phys = physical sciences (including geosciences); All = all STEM.

Data available in Appendix Table B-6.

Figure 5. International Percentage of Master's Degree Graduates in STEM Disciplines 2012–2021

3. Doctoral Degrees

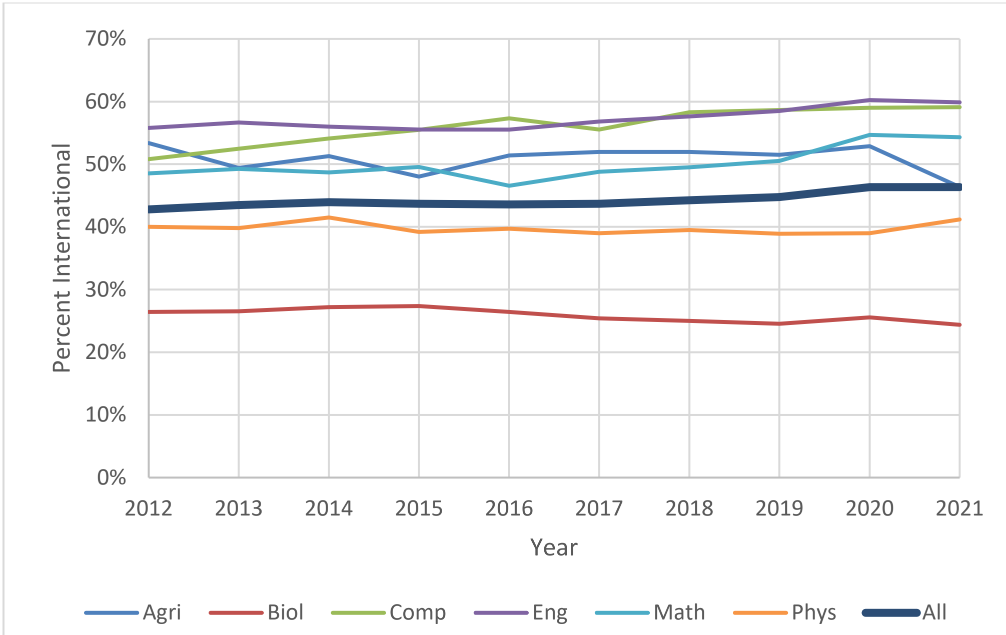
The total number of students receiving doctoral degrees in a STEM discipline in the United States increased from 25,714 in 2012 to a peak of 30,552 in 2020 followed by a drop to 29,588 in 2021 (Appendix B). The overall trajectories of both domestic and international students share a similar pattern: a sharp rise from 2012 to 2014, a level step from 2014 to 2016, a rise from 2016 to 2019 or 2020, and a drop from 2019 or 2020 to 2021 (Figure 6). Overall, the number of international students receiving STEM doctoral degrees increased by over 2,500 from 11,005 in 2012 to 13,716 in 2021; the number of domestic STEM doctoral degrees completed over the same period increased by just over 1,000 from 14,709 to 15,872.



Note: Data available in Appendix Tables B-7 and B-8.

Figure 6. Number of International (blue) and Domestic (red) Students Receiving a Doctoral Degree in a STEM Discipline 2012–2021

The percentage of U.S. STEM doctoral degrees awarded to international students increased from 42.8% in 2012 to 46.4% in 2021 (Figure 7), but the participation of international students varied substantially by STEM discipline. The proportion of doctoral degrees awarded to international students was about 25% in the biological and biomedical sciences, about 40% in the physical sciences, and around 50% in agriculture and related sciences; all three STEM areas showed no consistent change or a slight decrease in the proportion of international students earning doctorates between 2012 and 2021. In contrast, the proportion of doctoral degrees awarded to international students increased from 48.5% to 54.3% in mathematics and statistics, 55.8% to 59.9% in engineering, and 50.8% to 59.1% in computer and informational sciences between 2012 and 2021.

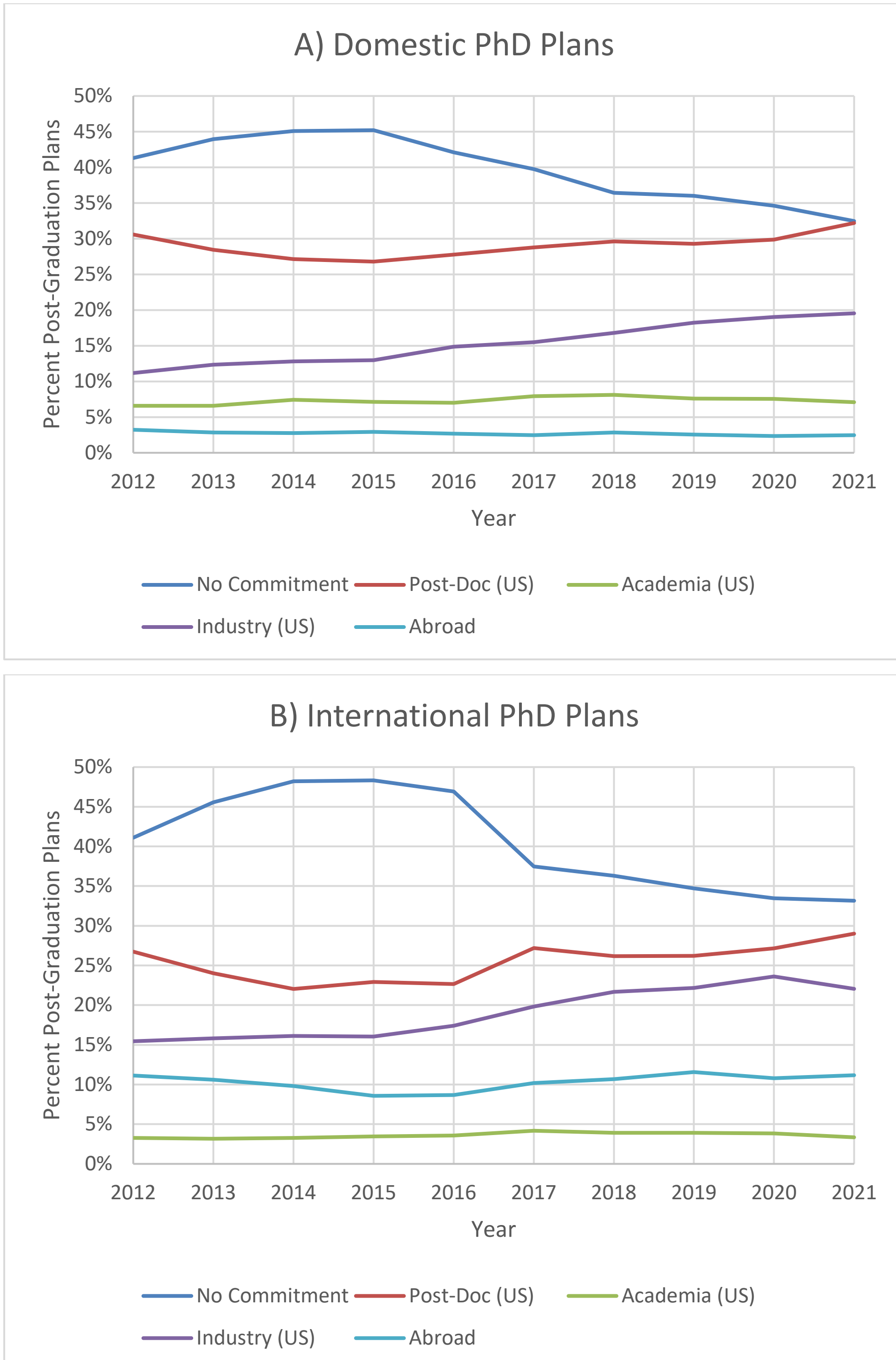


Notes: Agri = agriculture and related sciences; Biol = biological and biomedical sciences; Comp = computer and information sciences; Eng = engineering; Math = mathematics and statistics; Phys = physical sciences (including geosciences); All = all STEM.

Data available in Appendix Table B-9.

Figure 7. International Percentage of Doctoral Degree Graduates in STEM Disciplines 2012–2021

Unlike bachelor's and master's graduates, information about the post-graduation intentions of doctoral students completing degrees in the United States is known thanks to NSF's SED. From 2017 to 2021, fewer than 40% of both domestic and international STEM doctoral recipients reported having no post-graduation commitments, a decrease of high values of 45.1% for domestic students and 48.2% for international students in 2014 (Figure 8). Throughout the period of 2012 to 2021, about 10% of international doctoral recipients reported plans to leave the United States compared to only 2–3% of domestic students (Figure 8). Both groups also differed in the proportion reporting plans to go into academia in the United States: only about 3.5% of international doctoral recipients compared to 8% of domestic doctoral recipients. Between 2012 and 2021, both international and domestic doctoral recipients show increases in the proportion of graduates planning to go into industry, from 11% to almost 20% for domestic students and from 15% to 23% for international students. Lastly, the proportion of domestic students indicating that they plan to take a post-doc in the United States starts at 30.6% in 2012, dips to a low of 26.8% in 2015 and rises back up to 32.2% in 2021, whereas the proportion of international students reporting that they plan to take a post-doc in the United States starts at 26.8% in 2012, falls to 22.0% in 2014, jumps up to 27.2% in 2017, and remains around 29.0% until 2021.



Note: Data available in Appendix Tables B-10 and B-11.

Figure 8. Post-Graduation Commitments Reported by Domestic and International U.S. Doctoral Degree Recipients 2012–2021

Several studies have followed international graduates of STEM doctoral programs in the United States over longer time periods to quantify retention. Based on data from NSF's

SDR from 2008 through 2013, Finn and Pennington (2018) found that 72% to 77% of international doctoral graduates in science or engineering fields remained in the United States after 5 years and 67% to 71% remained after 10 years. Corrigan et al. (2022) examined data from 2000 to 2015 and found that 77% of international doctoral graduates over that period were still in the United States in 2015. Over the long term, these figures indicate an annual loss of 2,800 to 3,500 international STEM doctoral graduates who graduated between 2012 and 2021.

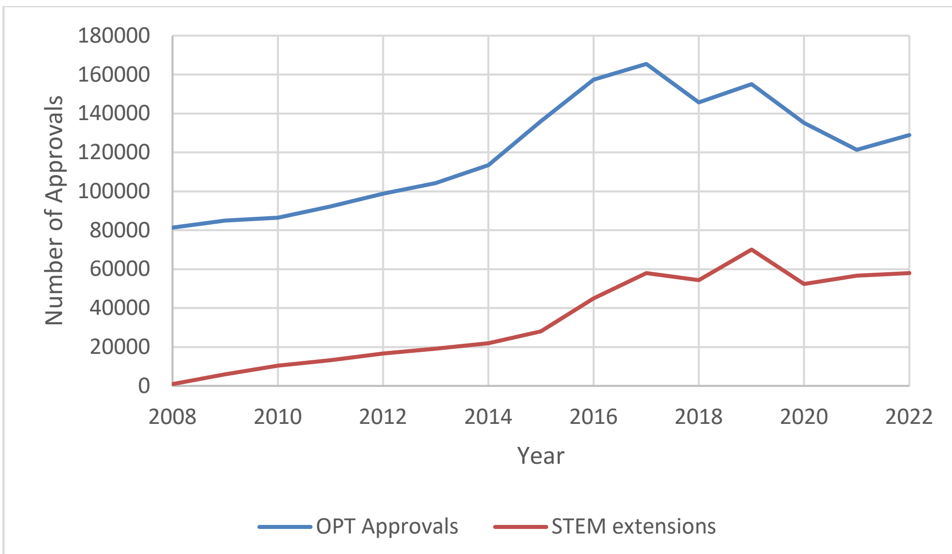
D. Estimating the Number of International STEM Students Who Leave the United States

The U.S. STEM ecosystem depends on a constant influx of graduates from the country's system of higher education. Although not all students completing a STEM degree choose to pursue a career in STEM—and as a consequence are lost from the STEM ecosystem—only international graduates (i.e., those who had F-1 visa status) must leave the United States within 60 days of completing their degree unless they find employment, continue their studies by pursuing an additional or advanced degree, or otherwise change their visa status. Data from USCIS provide some insight into the magnitude of the loss of international STEM graduates by tracking those who choose to pursue OPT and eventually transition to a temporary work visa (Appendix B). The publicly available Federal data on the post-graduation paths of international students do not identify their field of study, limiting estimates of post-graduation STEM talent flow and loss.

1. Estimating the Number of STEM Graduates Participating in Optional Practical Training

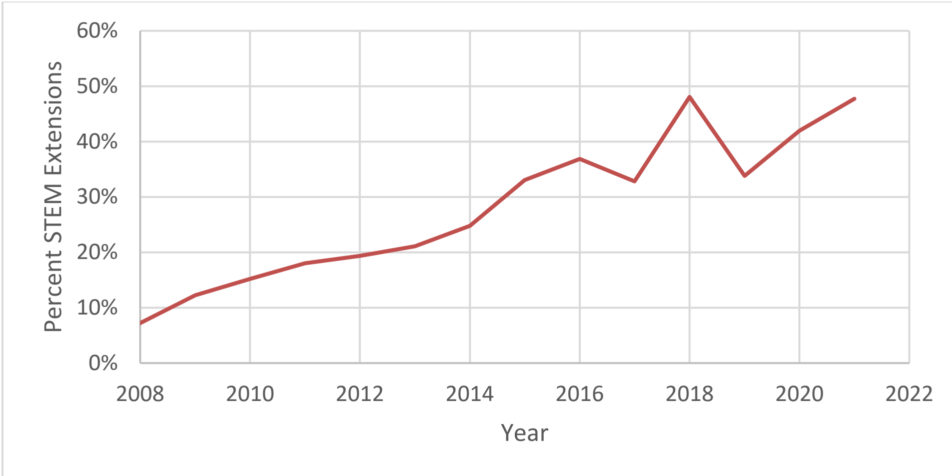
The OPT program allows international graduates from U.S. institutions of higher education to stay and work in the United States on an F-1 student visa. STEM students in particular are eligible for a 24-month extension on top of the normal 12-month OPT duration (USCIS 2023a). The extended OPT period for international STEM students allows employers to submit LCA applications for an H-1B visa multiple times for an international graduate who wishes to pursue employment in the United States, thereby increasing their chances of entering the U.S. STEM workforce. The number of STEM graduates taking advantage of OPT increased after the extension was instituted in 2008, not just because more international students chose to use the longer OPT window but also because more international students chose a STEM major: Amuedo-Dorantes et al. (2019) documented that the OPT STEM extension was followed by an increase in the likelihood of international students choosing a STEM major by about 18%. Similarly, Beine et al. (2022) report an increase in the transition of STEM graduates to the U.S. workforce after the 2008 OPT STEM extension was implemented.

Prior to the establishment of the first OPT extension for STEM graduates in 2008, between 80,000 and 90,000 OPT applications were approved for all academic majors. Since the first STEM extension, the total number of OPT approvals rose to 136,000 in 2015, after which it varied between 145,000 and 165,000 from 2016 to 2019 before dropping to just over 120,000 from 2020 to 2022 (Figure 9). (The reason for the dramatic drop after 2019 is uncertain, but the timing coincides with the COVID-19 pandemic.) Starting in 2008, when the STEM extension was established, the number of approvals rose to 58,000 in 2017, after which it fluctuated between 52,500 and 70,000 until 2022 (Figure 9). Because STEM extensions are required after the initial 12-month OPT window, the number of STEM extensions in a given year provides a minimum estimate of the number of applicants with a STEM major in the previous year: by 2016, at least 35% to 45% of OPT applications were from students with STEM-approved majors (Figure 10).



Note: Data available in Appendix Table B-12.

Figure 9. OPT Approvals and STEM Extension Approvals 2008–2022



Note: Data available in Appendix Table B-12.

Figure 10. Percentage of STEM Extensions as a Percentage of OPT Approvals in the Previous Year

The number of STEM OPT extensions provides only a minimum estimate of the number of OPT students in STEM fields. A full estimate of the proportion of international STEM graduates who stay in the United States immediately after graduation requires additional, non-public information. Using data obtained through a Freedom of Information Act request to USCIS, Ruiz and Budiman (2018) found that 53% of OPT approvals went to international graduates in STEM fields between 2004 and 2016. In addition, they found that STEM master's graduates made up 34% of all authorized OPT enrollees. Within different degree levels, they reported that STEM graduates made up 78% of all OPT approvals of doctoral students, 60% of all master's students, and 33% of all bachelor's students. In a separate study, Demirci (2019) found that 72% of all international graduates stayed on F-1 visa status more than 60 days past their graduation between 2004 and 2014 (information on the proportion staying to continue studies versus transitioning to OPT was not available in Demirci's data).

The information on retention immediately after graduation (Demirci 2019) and the proportions of STEM graduates making use of the OPT program (Ruiz and Budiman 2018; Table 2), in combination with the number of international STEM graduates from U.S. institutions and the number of OPT approvals each year (Table 3), can be used to estimate the number of international STEM students who leave the U.S. STEM ecosystem shortly upon completing their studies using two different approaches that yield similar results (Tables 4 and 5). Starting with the number of international STEM graduates in 2021 (104,000; Appendix B), both methods indicate that approximately 75,000 to 76,000 international STEM students remained on F-1 status after graduation, indicating that 28,000 to 29,000 either left the United States or changed visa status.

Table 2. Retention of International STEM Students and Participation in OPT

Percentage of all international students who remain in United States on F-1 visa after graduation (Demirci 2019)	72%
Percentage of international STEM doctoral students who remain in United States on F-1 visa after graduation (Demirci 2019)	85%
Percentage of international STEM master's students who remain in United States on F-1 visa after graduation (Demirci 2019)	89%
Percentage of all OPT approvals awarded to STEM graduates (Ruiz and Budiman 2019)	53%

Table 3. Annual Number of International STEM Graduates and OPT Approvals

Number of international STEM graduates in 2021 (IPEDS NCES)	104,000	
Doctoral graduates (2021)	14,000	13.5%
Master's graduates (2021)	60,000	57.7%
Bachelor's graduates (2021)	30,000	28.8%
Average number of OPT approvals per year (2016–2020) (USCIS)	144,000	

Table 4. Estimated Loss of International STEM Students Based on Total OPT Approvals

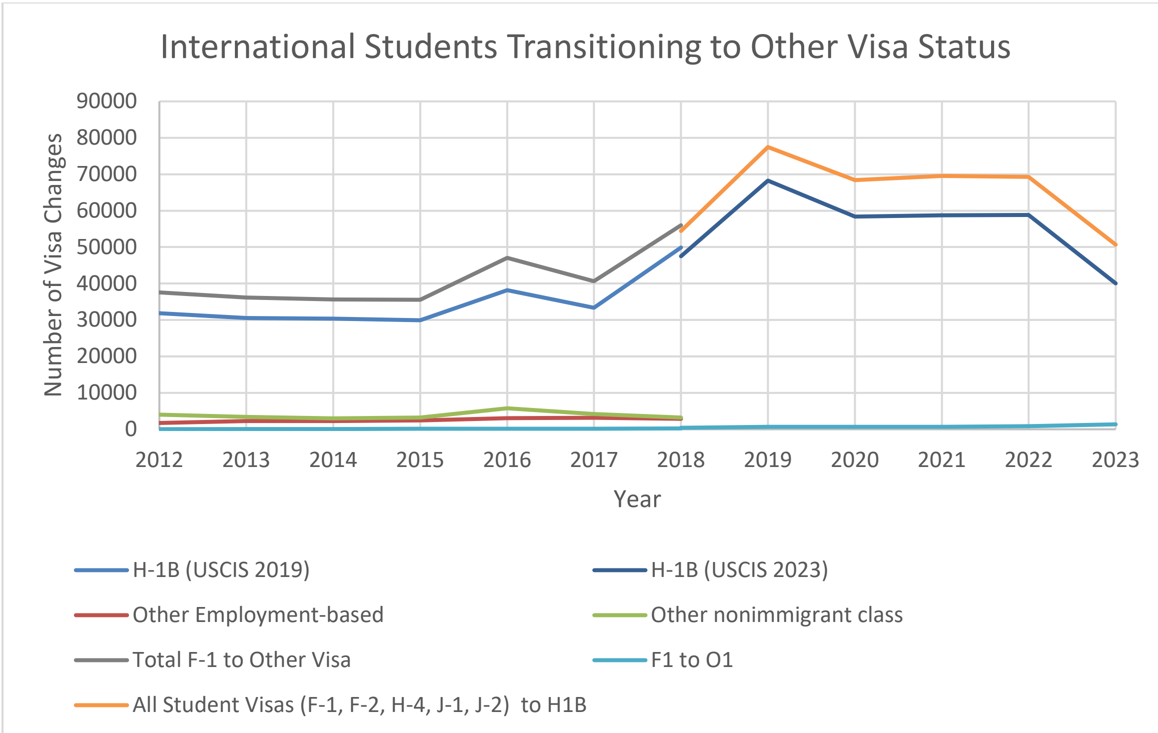
Number of STEM OPT approvals:	144,000 x 53% =	76,300
Number of STEM students lost upon graduation or to another visa status:	104,000 – 76,300 =	27,700

Table 5. Estimated Loss of International STEM Students Based on STEM Participation in OPT

Number of STEM students remaining in United States on F-1 visa after graduation:	104,000 x 72% =	74,900	
Number of STEM students lost upon graduation or transition to another visa status:	104,000 – 74,900 =	29,100	
Breakdown by degree level			
Percentage of STEM students who earned a doctoral degree and remain in the United States on F-1 visa after graduation:	85% x 13.5% =		12%
Number who stay:	12% x 104,000 =	12,000	
Number lost:	14,000 – 12,000 =	2,000	
Percentage of STEM students earning a master's degree and remaining in the United States on F-1 visa after graduation:	89% x 57.7% =		51%
Number who stay:	51% x 104,000 =	53,000	
Number lost:	60,000 – 53,000 =	7,000	
Percentage of STEM students earning a bachelor's degree and remaining in the United States on F-1 visa after graduation:	72% - (12% + 51%) =		9%
Number who stay:	9% x 104,000 =	9,500	
Number lost:	30,000 – 9,500 =	20,500	
Percentage of STEM bachelor's graduates who remain in the United States on F-1 visa after graduation:	9500 ÷ 30,000 =		32%

2. Estimating the Number of STEM Graduates Transitioning to Temporary Work Status

Although OPT allows international STEM students to stay and work in the United States for up to 36 months after graduation, F-1 visa holders must eventually transition to a different visa status or leave the United States. USCIS (2019, 2023d) has published data on the number of F-1 visa transitions in two separate fact sheets. The first (USCIS 2019), which spans from 2008 to 2018, reports on the transition of F-1 visas to other nonimmigrant visa statuses, but does not provide information on other education-related visas (e.g., J-1). The second (USCIS 2023d), which spans from 2018 to 2023, provides data on the transition to H-1B visa status from several education-related visa types (F-1, F-2, H-4, J-1, and J-2), but not to other visa types (e.g., O-1). Neither report breaks out STEM from non-STEM students. Together, the two fact sheets provide an incomplete but continuous record of the number of international students who eventually stay as H-1B temporary workers in the United States.



Notes: Data available in Appendix Tables B-13 and B-14.

Data from 2012 to 2018 are from USCIS (2019) and data from 2018 to 2023 are from USCIS (2023d). The break in the number of F-1 visas transitioning to H-1B visas in 2018 represents a small discrepancy between the two data sets.

Figure 11. Number of Changes from F-1 to Other Nonimmigrant Visa Status 2012–2023

The total number of F-1 to H-1B status changes ranged from 30,000 to 38,000 between 2012 and 2017 and then rose from 48,000 in 2018 to over 68,000 in 2019 before dropping to around 58,000 through 2022 (the number dropped further to 40,000 in 2023; Figure 11). Between 2012 and 2018, an additional 1,700 to 3,000 F-1 visa holders transitioned to other employment-based visas and 3,000 to 5,750 transitioned to non-employment-based visas. Comparable data on transitions from F-1 to non-H-1B visa status are not available after 2018. However, between 2018 and 2023, an additional 11,000 to 12,000 H-1B visas were approved for holders of F-2, H-4, and J-1 visas, bringing the total number of international students transitioning to H-1B status to nearly 70,000 annually from 2020 to 2022.

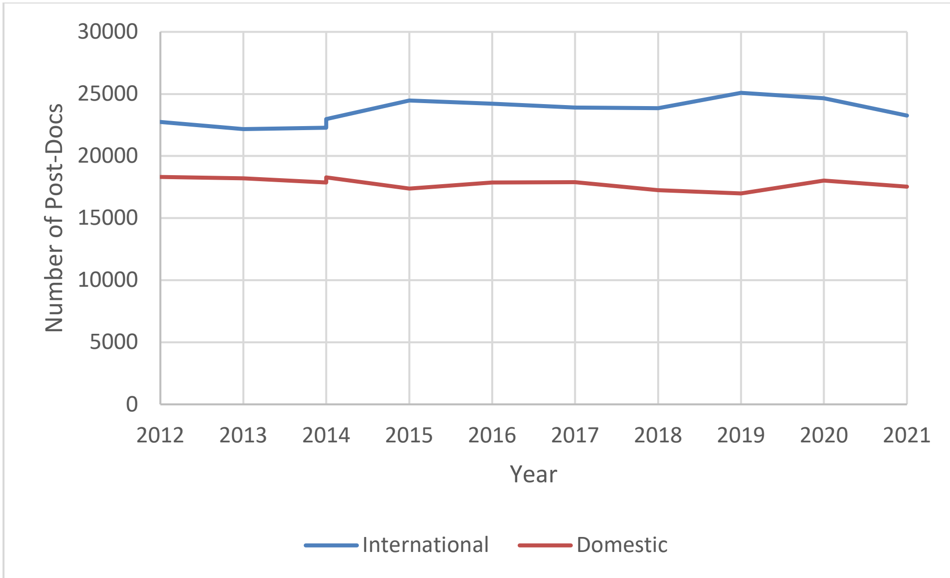
Applying Ruiz and Budiman's (2018) estimate that 53% of international students who stay on OPT are in STEM disciplines (Table 2) to the total number of international students transitioning to H-1B status suggests that approximately 32,000 2021 STEM graduates will transition from F-1 to H-1B status. In addition, approximately 1,200 F-1 STEM students transitioned to non-employment visa status and as many as 6,000 transitioned to H-1B from non-F-1 visa status. These figures suggest that of the 104,000 international STEM graduates in 2021, as many as 70,800 have left or will eventually leave the United States.

4. The Post-Doctoral Pool of STEM Talent

Post-doctoral scholars represent a pool of STEM talent that differs from both students and workers in several respects. Like students, post-doctoral positions are widely considered a stage of professional training for careers conducting research in the industrial or academic sectors. In addition, because their positions are typically tied to specific research grants or fixed-term fellowships, post-docs, like students, are inherently transient. Yet, post-docs have completed their formal education and often have skills and knowledge comparable to highly skilled STEM workers in industry or academics. They also are treated differently than students in terms of their visa status: Although international post-docs who graduated from a U.S. institution can start their positions on F-1 status as OPT, they must eventually obtain a visa permitting them to work in the United States if they stay in their position longer than 3 years (typically H-1B and more rarely J-1 status). Post-docs coming to the United States directly from overseas must start their positions on temporary work visas. However, since post-docs largely work in academic and research settings, most are not subject to the cap on H-1B visas that applies to foreign nationals seeking private sector employment.

Unlike students, post-docs do not graduate, making the number of people entering or leaving the post-doctoral talent pool each year less straightforward to assess than the number of STEM students receiving degrees each year. Based on data from NCSES, the total number of post-docs in STEM disciplines in the United States was fairly steady between 2012 and 2021, ranging between 41,082 to 42,668 (Appendix C); the number of international post-docs ranged between 22,168 and 25,089, and the number of domestic post-docs ranged from 16,988 to 18,315 (Figure 12).

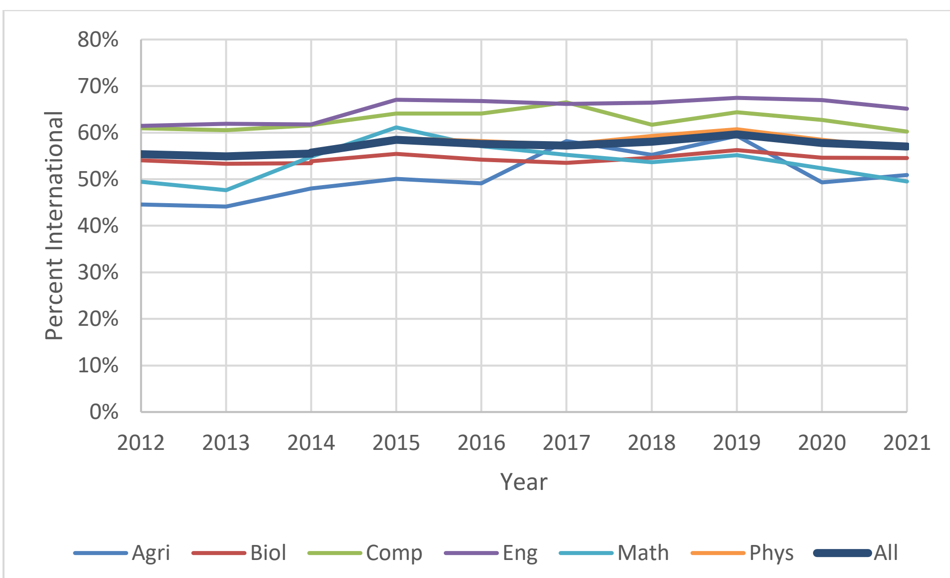
International scholars made up a majority of all STEM post-docs in the United States over the entire 2012 to 2021 period, ranging from 55% to 60% with no systematic increase or decrease (Figure 13). The large proportion of international scholars in U.S. STEM post-docs is not limited to just one or a few STEM disciplines: between 2012 and 2021, they made up no less than 44.1% in agriculture and related sciences and as much as 66.5% in computer and information science and 67.5% in engineering.



Notes: Data available in Appendix Tables C-1 and C-2.

Counts from before and after 2014 are not strictly comparable due to an update in the survey frame used by NCSES that identified potentially eligible but not previously surveyed academic institutions in the United States with STEM research programs. A total of 151 newly eligible institutions were added in 2014, and 2 private for-profit institutions were dropped. Data for 2014 are reported using both survey frames, resulting in the small kink visible in 2014 in Figure 12.

Figure 12. Number of International (blue) and Domestic (red) Post-Doctoral Scholars in STEM Disciplines 2012–2021

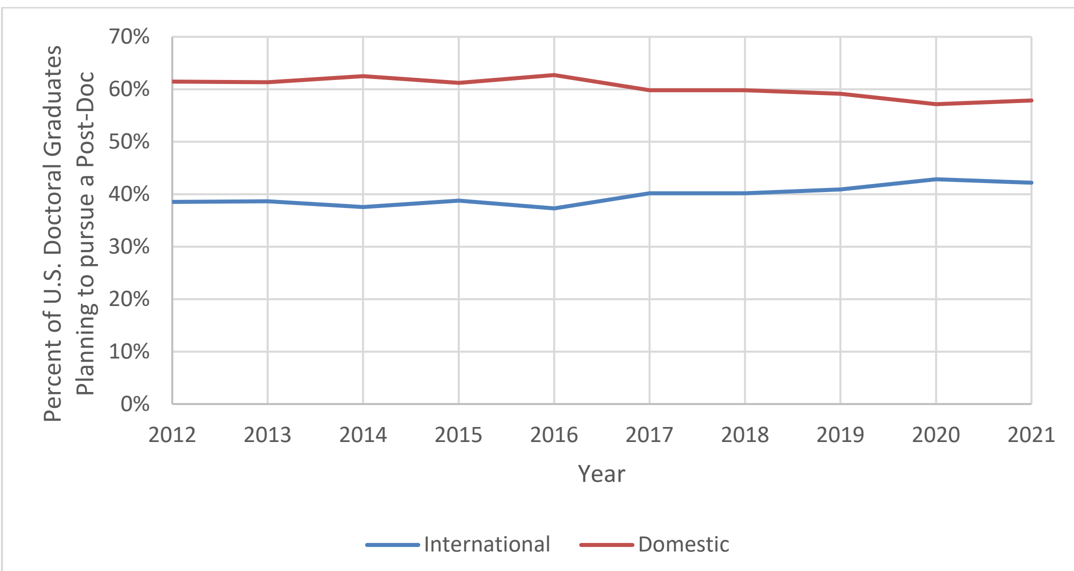


Notes: Data available in Appendix Table C-3.

Agri = agriculture and related sciences; Biol = biological and biomedical sciences; Comp = computer and information sciences; Eng = engineering; Math = mathematics and statistics; Phys = physical sciences (including geosciences); All = all STEM.

Figure 13. Percentage of International Post-Doctoral Scholars in STEM Disciplines 2012–2021

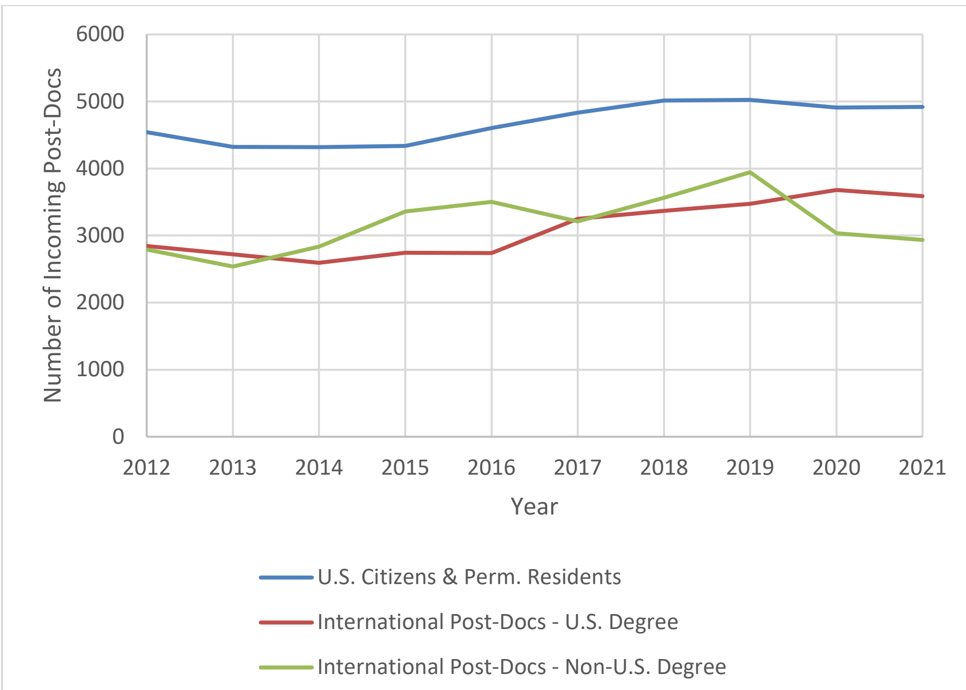
The data on international post-docs reported by NCSES do not distinguish those who transitioned into their positions after obtaining a doctoral degree from a U.S. institution versus those who were recruited from outside the United States. However, information on the proportion of domestic and international STEM doctoral graduates from U.S. institutions, compared to the total proportion of international post-docs, can be used to estimate the number drawn from outside the United States each year. Using information from NSF's SED on the plans of doctoral graduates from U.S. institutions (Figure 8), of all the doctoral students graduating from U.S. institutions indicating that they planned to start a post-doc position in the United States, 39% to 42% were international and 58% to 61% were domestic (Figure 14). The difference between the proportion of U.S.-trained international doctoral students taking U.S.-based post-docs and the total proportion of international post-docs in the United States is made up by post-doctoral scholars recruited from outside the country (see Appendix C-4 for calculation). Between 26% and 32% of all STEM post-docs annually starting positions in the United States were recruited from outside the country (45% to 55% of all international post-docs starting annually in the United States).



Note: Data available in Appendix Tables B-10 and B-11.

Figure 14. Proportion of Doctoral Graduates from U.S. Institutions Who Report Plans to Take a Post-doctoral Position in the United States 2012–2021

Applying the percentage of foreign-trained post-docs to the number of U.S. doctoral students reporting an intention to start a post-doc position indicates that at least 2,500 to 3,500 foreign-trained post-docs come to the United States each year (Figure 15), although this is likely an underestimate because the number of respondents to NSF's SED is smaller than the total number of doctoral graduates. Nevertheless, these estimates indicate that in addition to retaining a large proportion of international STEM doctoral graduates from U.S. institutions, the U.S. STEM ecosystem also attracts several thousand more doctoral-level STEM scholars each year. Demirci (2019) found that 85% of STEM doctoral graduates did not leave the United States upon graduation (Table 2); given that approximately 14,000 international students graduated with a STEM doctorate from a U.S. institution in 2021 (Table 3), this indicates that the number of doctoral scholars recruited each year from overseas for post-doctoral positions exceeds the number of U.S.-trained doctorates who leave shortly after graduation (approximately 2,100 in 2021). Retention of U.S.-trained post-doctoral scholars is folded into the long-term doctoral retention rate of about 75% reported by Finn and Pennington (2018) and Corrigan et al. (2022); data on the retention rate of post-doctoral scholars recruited from non-U.S. institutions was not found.



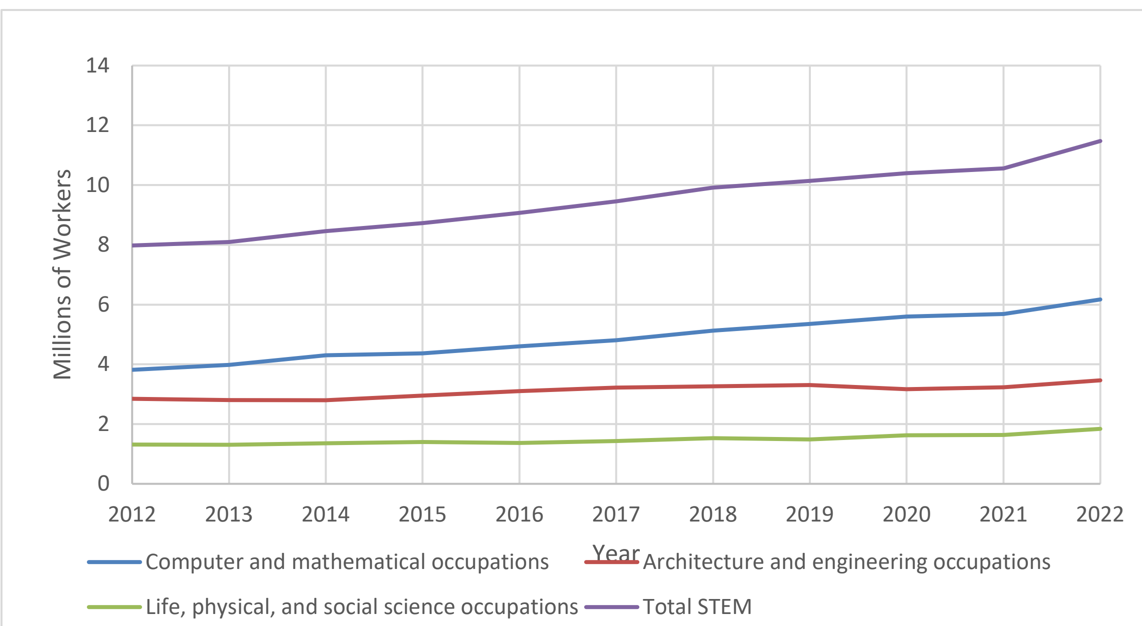
Note: Data available in Appendix Table C-4.

Figure 15. Annual Influx of Foreign-trained Post-docs, U.S.-trained International Post-docs, and U.S.-trained Domestic Post-docs to the U.S. STEM Ecosystem 2012–2021

5. The STEM Workforce

The U.S. STEM workforce employed 11.5 million workers in 2022 (Figure 16). Remarkably, flows from the U.S. STEM education system are only loosely coupled with the highly skilled STEM workforce: Using data from the U.S. Census, Day and Martinez (2021) report that 62% of college-educated workers who majored in a STEM field are employed in non-STEM occupations (non-STEM management, law, education, social work, accounting, or counseling). Conversely, 13% of workers in STEM occupations do not have a degree in a STEM field (Okrent and Burke 2021). The portion of the U.S. STEM workforce that did not earn a STEM degree in the United States represents (1) talent flowing in from non-STEM positions and (2) workers coming to the United States from overseas.

U.S. Citizens and permanent residents face few restrictions on employment, but foreign STEM workers face substantial statutory constraints on their access to the U.S. labor market, who they can work for, and how long they can stay. Since non-citizens make up a substantial fraction of the U.S. STEM workforce, characterizing the flows of foreign workers is important for understanding where the U.S. STEM ecosystem may be leaking talent.



Note: Data available in Appendix Table D-1.

Figure 16. The U.S. STEM Workforce 2012–2022

A. Why High-Skilled STEM Talent Comes to the United States

High-skilled migrants—i.e., those with a tertiary education, skills, or knowledge that make them readily employable in occupations that enhance a nation's economic, cultural, or knowledge capacity—can increasingly choose where they live and work as part of a global labor market (Czaika 2018). In the international competition to attract and retain high-skilled talent, the United States has historically fared well and continues to be a highly attractive destination. In 2023, the United States was ranked as the eighth most attractive destination among OECD countries for highly skilled workers based on eight criteria (Dumont and Andersson 2023):[13]

1. Quality of opportunity: low migrant unemployment and low over-qualification rate;
2. Income and tax: favorable earnings, taxation, and cost of living;
3. Future prospects: ease of obtaining permanent residency;
4. Family environment: quality of education, spousal employment opportunity;
5. Skills environment: knowledge infrastructure (e.g., broadband) and national expenditure on research and development;
6. Inclusiveness: share of migrants in population and migrant acceptance;
7. Quality of life: high OECD Better Life Index measuring material and personal well-being; and
8. Visa and admission policy: low visa refusal rates and quotas.

The U.S. ranking is penalized by unfavorable visa and admissions policies (high visa refusal rates and a tight quota on highly skilled migrants), without which the United States would be the second most attractive OECD destination for highly skilled migrants. In addition, the attractiveness ranking of the United States also suffers based on the structure and performance of its health system, particularly during the COVID-19 pandemic (Dumont and Andersson 2023).

The few identified studies that specifically address the attractiveness of the United States for STEM workers largely focus on the academic sector rather than the broader STEM workforce. The GlobSci Survey (Franzoni et al. 2012) found that the United States was the fourth highest country in terms of the proportion of scientists who are immigrants, although the size of the U.S. STEM ecosystem means that it has the largest absolute number of immigrant scientists of any country included in the survey (van Noorden 2012). Based

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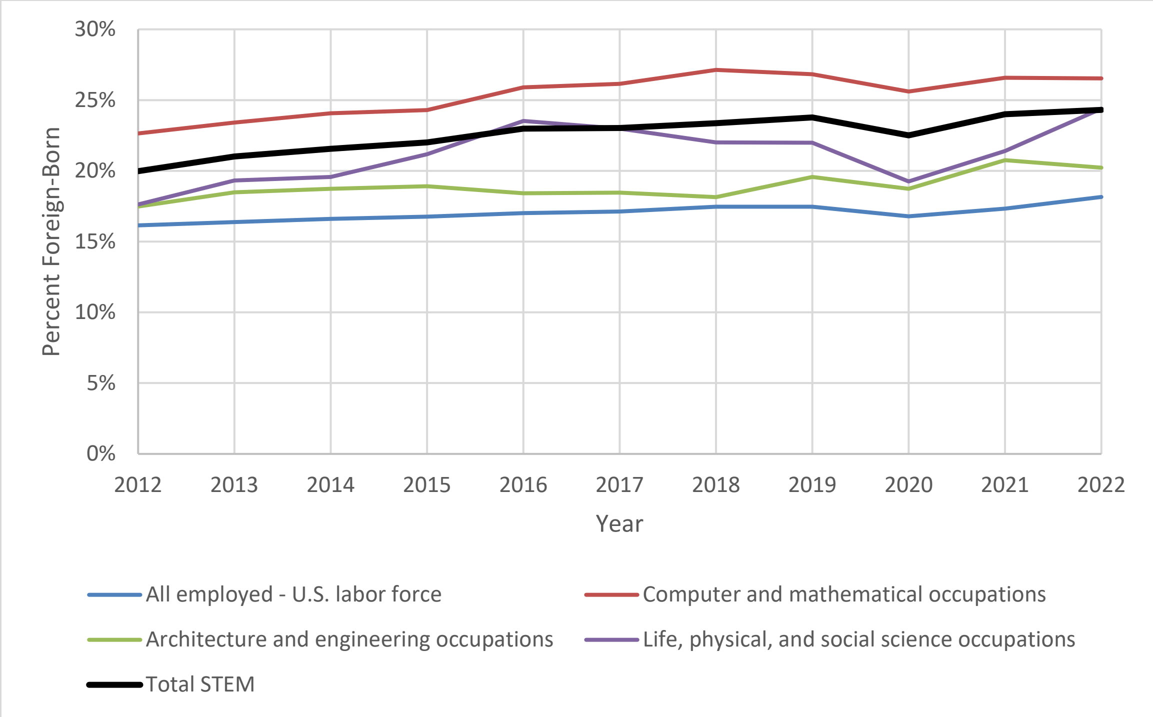
[13] The top 10 OECD countries for highly skilled foreign workers, in order, are: New Zealand, Sweden, Switzerland, Australia, Norway, Luxembourg, Great Britain, the United States, the Netherlands, and Canada (Dumont and Andersson 2023).

on analysis of chemistry faculty at U.S. universities from 1993 to 2007, Goulé (2014) found that 83% of foreign-born faculty (based on where they earned their bachelor's degree) stayed in the United States, 7% returned to their home country, and 3% went to another foreign country during the time period covered by the study (the remainder either died or retired).

B. Estimating the Flows of Foreign STEM Talent into and out of the U.S. Workforce

Data from the U.S. Census Bureau indicate that 2.8 million immigrants were employed in the U.S. STEM workforce in 2022 (Appendix Table D-2)—24% of all employed U.S. STEM workers. Of foreign-born workers in STEM occupations, just over half are non-citizens, who compose 13% of all U.S. workers in computer, engineering, and science occupations (U.S. Census Bureau 2022). Data from BLS indicate that foreign-born workers made up 27% of those in computer and mathematical occupations, 20% in architectural and engineering occupations, and 24% in life, physical, and social science occupations in 2022 (Figure 17). Although the proportion of foreign-born workers in each occupation category has fluctuated over the past decade, the trend for STEM as a whole displays a consistent increase in the proportion of foreign-born workers from 20% in 2012 to 24% in 2022, a trajectory consistent since the beginning of the 21st century (American Immigration Council 2022).

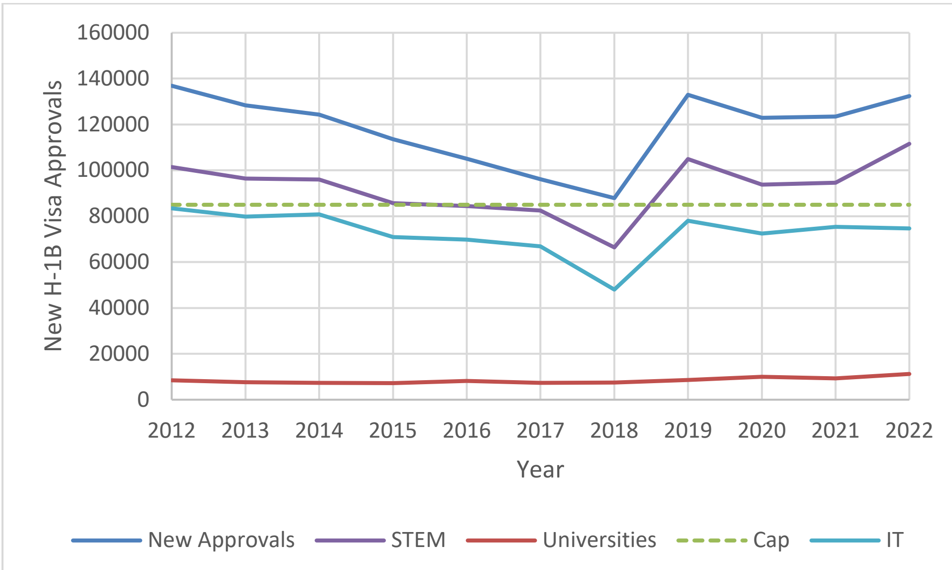


Note: Data available in Appendix Table D-2.

Figure 17. Percentage of Foreign-Born Workers in STEM Occupations 2012–2022

1. Estimating the Number of Foreign Temporary Workers in STEM

The primary means for immigrants to enter the U.S. labor market is through the H-1B visa. From 2012 to 2018, the number of new H-1B approvals decreased from 137,000 to 88,000 before it sharply rose to 133,000 in 2019, fell to 123,000 in 2020 and 2021, and rose again to 132,000 in 2022 (Figure 18).[14]



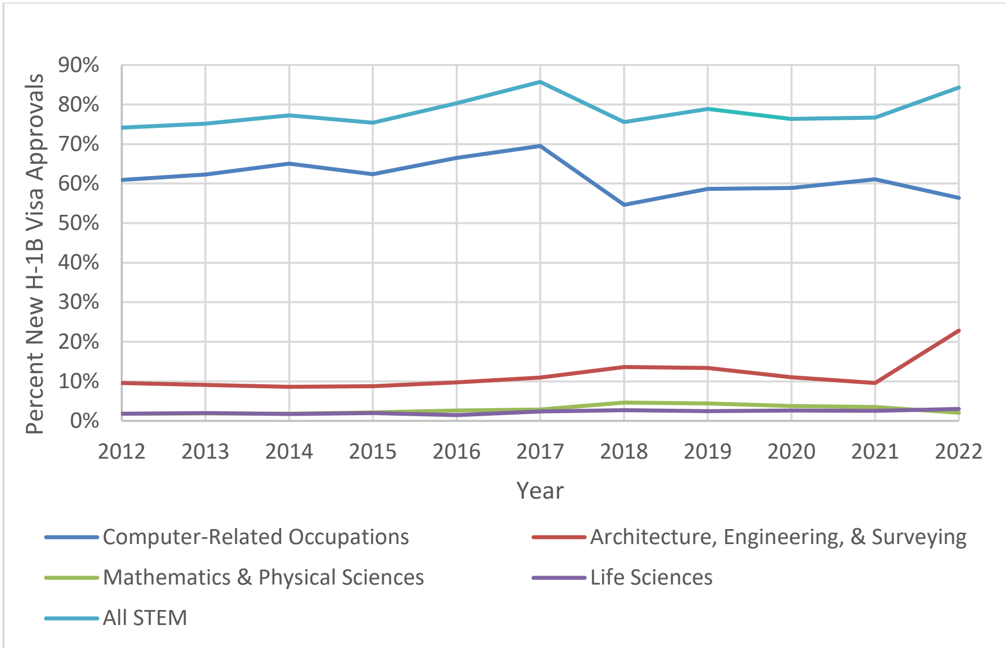
Notes: New Approvals = all new H-1B approvals; STEM = new H-1B approvals in STEM occupational areas; IT = new H-1B approvals in computer science and information technology; Universities = new H-1B approvals exempt from the annual cap due to employment at an approved academic institution (STEM and non-STEM).

Data available in Appendix Table D-3.

Figure 18. Number of New H-1B Visa Approvals 2012–2022

H-1B visa approvals are dominated by STEM talent, varying between 74% and 85% of all approvals over the past decade. Most temporary STEM workers were in computer-related occupations, which account for an average of 62% of all new H-1B visa approvals (Figure 19). Colleges and universities account for only 7,200 to 11,000 (6.0% to 8.5%) of annual H-1B approvals; this number likely includes most international post-doctoral scholars, both those who completed their doctoral degrees in the United States and those who were recruited from non-U.S. institutions.

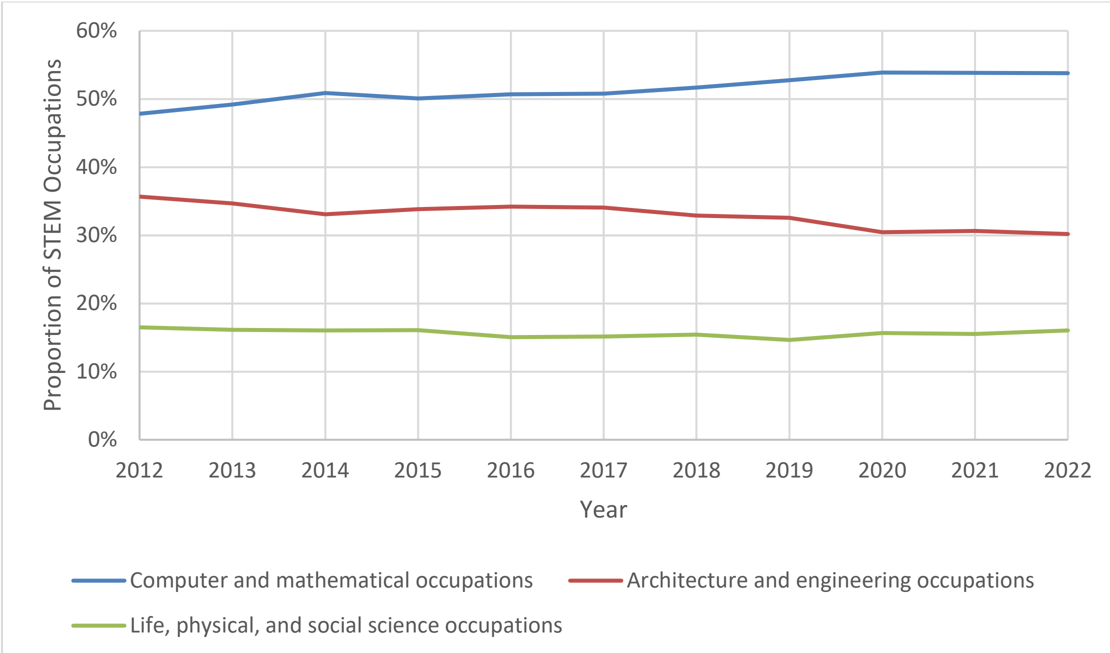
[14] The reason for the decrease in new H-1B approvals from 2012 to 2018 and the sharp rise in 2019 was not explored. According to Anderson (2023), the denial rate for H-1B petitions for new employment increased from 5–8% from 2012 to 2015 to a peak of 24% in 2018 and 21% in 2019 before decreasing to 4% in 2021 and 2% in 2022. The changes reflect shifts in the policy of different Presidential administrations; the drop starting in 2021 coincides with a legal settlement overturning Trump administration immigration policies.



Note: Data available in Appendix Table D-4.

Figure 19. Proportion of New H-1B Visas Approvals by STEM Occupational Category 2012–2022

As proportions of foreign STEM talent entering the U.S. labor market, computer-related workers represent 79%; architects, engineers, and surveyors represent 15%; and those in mathematics and physical sciences plus life sciences together represent 7%. These inflow proportions differ from the proportions of roughly equivalent occupational categories of foreign-born STEM talent in the United States, where 58% of foreign-born STEM talent is in a computer-related or mathematical occupation, 28% is in an architecture or engineering occupation, and 15% is in a life, physical, or social science occupation (Figure 20).



Note: Data available in Appendix Table D-4.

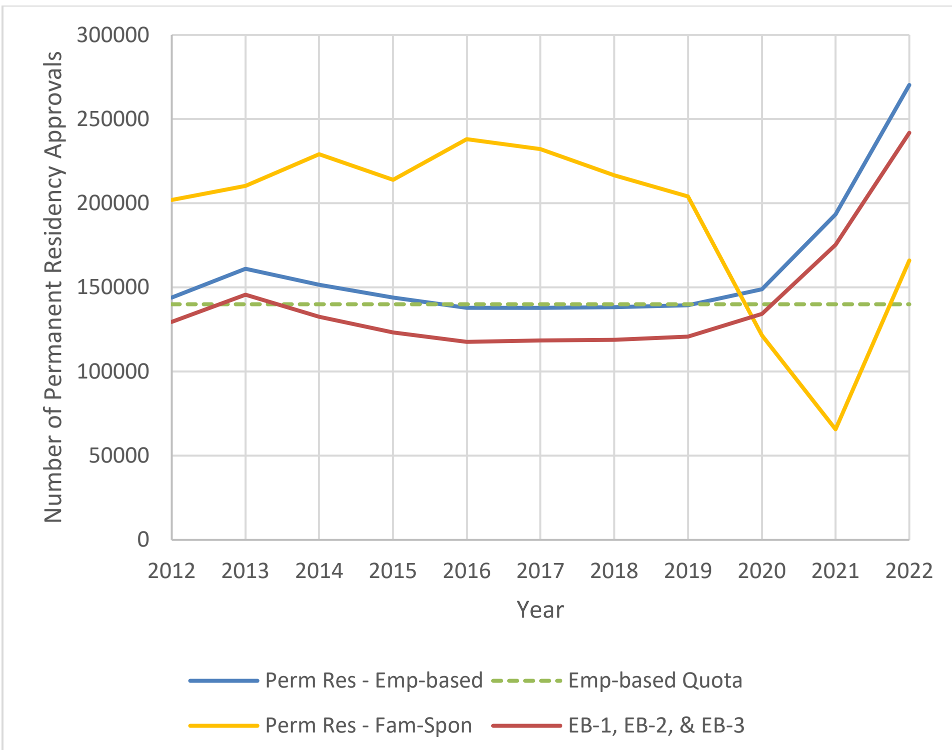
Figure 20. Changes in the Proportion of Occupational Categories in the U.S. STEM Workforce 2012–2022

Based on reported H-1B approvals, over 82,000 and as many as 115,000 STEM workers were added to the U.S. STEM workforce every year between 2012 and 2022 except 2018 (Figure 18). Of these, approximately 28,000 to 38,000 represent transitions from F-1 and other education-related visa status—i.e., international students already in the United States (see section *Estimating the Number of STEM Graduates Transitioning to Temporary Work Status)*—leaving roughly between 55,000 and 75,000 temporary foreign workers entering the United States to join the U.S. STEM workforce each year.

2. Estimating How Much Foreign STEM Talent Transitions to Permanent Residency

H-1B and other work visas are not permanent, and when they expire, foreign workers must either leave, change to another visa status, or seek permanent residency. Data on the number of foreign temporary workers who leave the United States either by choice or because their visa expired was not found. However, the number of annual approvals for STEM-based employment-based LPR status—i.e., the number of foreign STEM workers who have the opportunity to stay in the United States—can be estimated based on available information.

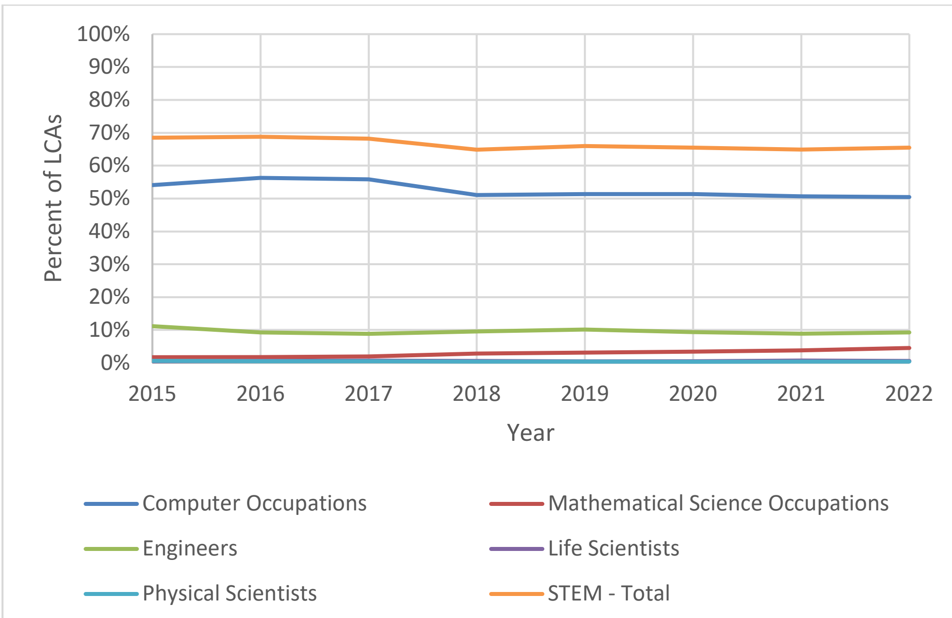
The total number of employment-based LPR approvals (i.e., “green cards”) is capped at 140,000 per year plus unused family-sponsored approvals from the previous year. Between 2012 and 2020 the number of green cards awarded was at or just above the cap, but it rose precipitously to 193,000 in 2021 and 270,000 in 2022 (Figure 21) due to a substantial drop in the number of family-based approvals in 2020 and 2021 as a result of the COVID-19 pandemic (USCIS 2021). The number of permanent residents admitted from the top three preference categories (EB-1, EB-2, and EB-3)—i.e., those most relevant to high-skilled STEM talent—are consistently between 85% and 90% of the total number of employment-based green cards awarded, ranging from 118,000 to 146,000 between 2012 and 2020 but rising to 242,000 in 2022, in line with the rise in the total number of employment-based LPR approvals (Figure 21).



Notes: "Perm Res – Emp-based" = All employment-based LPR approvals; "Perm Res – Fam-Spon" = Family-sponsored LPR approvals.
Data available in Appendix Table D-5.

Figure 21. Number of Permanent Residency ("Green Card") Approvals 2012–2022

No publicly available data report how many new LPR approvals represent STEM workers. Instead, as a proxy, information derived from labor certifications for employment-based applications for permanent residency can be used to estimate the proportion of green cards tied to STEM occupations (Turner 2022). Certification data do not provide direct evidence that employers actually hired the applicants, but they do indicate what kinds of workers U.S. employers were interested in hiring. In the case of employment-based LPR, STEM occupations accounted for 65% to 69% of applications for LPR between 2015 and 2022; 50% to 56% were in computer-related occupations, 9% to 11% were for engineers, and all other STEM occupations accounted for 3% to 5% (Figure 22). These proportions are comparable to the proportions of computer science-related occupations; architecture, engineering, and surveying occupations; and the sum of physical, mathematical, and life sciences occupations observed in H-1B approvals (compare with Figure 19). The proportion of applications for EB-2 employment-based immigration visas in STEM fields are a bit higher than the certification-based estimates for all LPR applications; STEM occupations made up 77.7% to 73.2% of EB-2 petitions received from 2018 to 2022 and 80.0% to 76.1% for EB-1 approvals (the proportion of STEM occupations dropped to 58.0% for receipts and 70.2% for approvals in 2023; USCIS 2024b).



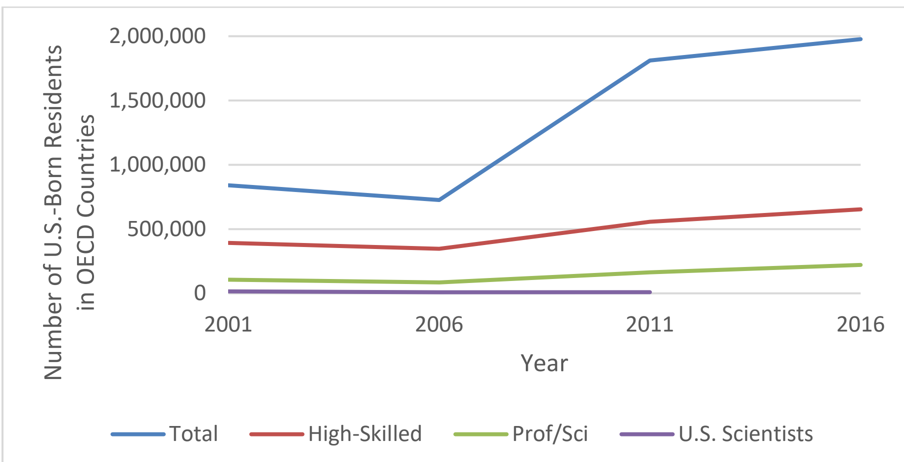
Notes: STEM occupations were not reported prior to 2015.
Data available in Appendix Table D-6.

Figure 22. Percentage of Labor Certifications for Employment-Based Permanent Residency in STEM Occupations 2015–2022

Applying this percentage to the sum of approvals in the three categories of employment-based LPR for highly skilled talent (EB-1, EB-2, and EB-3) results in 80,000 to 88,000 LPR approvals per year in STEM occupations in most years over the past decade, with possibly more than 150,000 in 2022. These numbers suggest that a large portion of STEM workers who start in the United States on temporary worker visas (82,000 to 112,000 annually), whether as international students who came to the United States to study or high-skilled workers brought by U.S. employers from overseas, have the opportunity to join the U.S. STEM ecosystem permanently. The numbers presented here do not account for the time it takes to be awarded a green card, which varies among immigrants from different nations due to country-based LPR approval caps. A more refined understanding of the transition to permanent residency than the rough numbers presented here will require additional analysis.

C. U.S.-Native STEM Talent Overseas

Minimal information is available regarding the number and occupations of American workers overseas, although the data that are available indicate that the emigration rate of high-skilled talent from the United States is very low (Kerr et al. 2016). A partial picture of the flow of native U.S. STEM talent can be obtained using data on the number, nationality, and occupation of immigrant workers in OECD countries compiled from national censuses of member states (OECD 2019). The total number of U.S.-born high-skilled residents in OECD countries (defined as those with tertiary education—i.e., any education beyond secondary or high school) ranged from 400,000 to 650,000 between 2001 and 2016 (Figure 23). Of those, between 100,000 and 200,000 were identified as "professionals"[15] but only 8,500 to 15,000 were identified as science and engineering professionals (OECD Occupational Sub-major Group 21[16]).



Notes: Total = total number of U.S.-born residents in other OECD countries; High-Skilled = High-skilled U.S. workers (i.e., tertiary education) in other OECD countries; Prof/Sci = U.S.-born workers counted in OECD Occupational Major Group 2; U.S. Scientists = U.S.-born workers counted in OECD Occupational Sub-major Group 2. Note: Data on U.S. scientists and engineers were not available for 2016.

Data available in Appendix Table E-1.

Figure 23. Reported Number of U.S.-born Foreign Residents in OECD Countries

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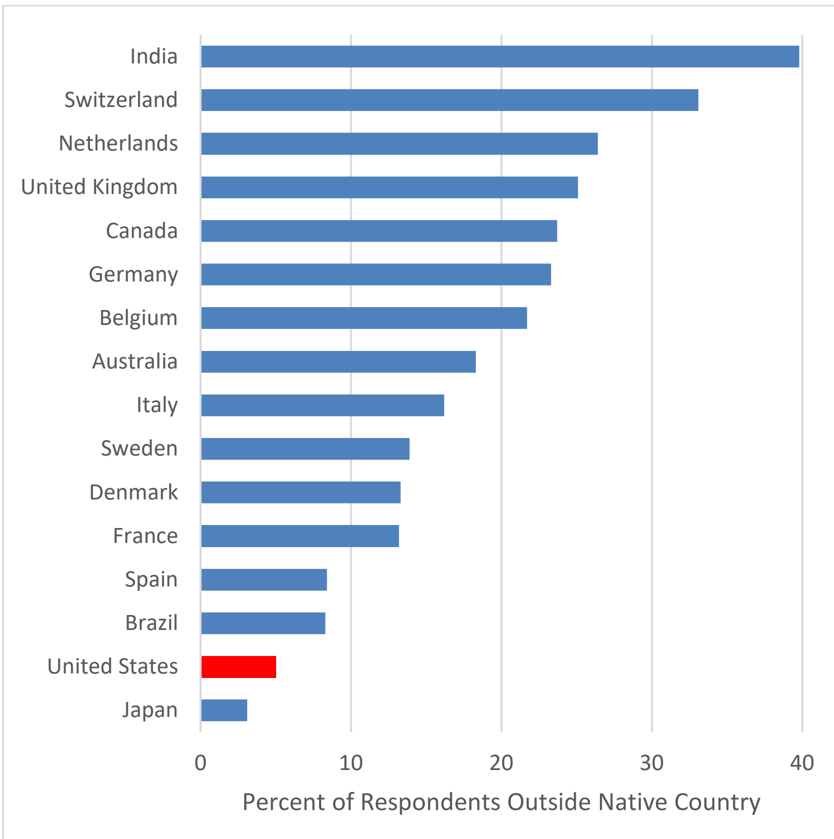
[15] OECD Occupational Major Group 2: "Professionals increase the existing stock of knowledge; apply scientific or artistic concepts and theories; teach about the foregoing in a systematic manner; or engage in any combination of these activities" (International Labour Organisation 2016).

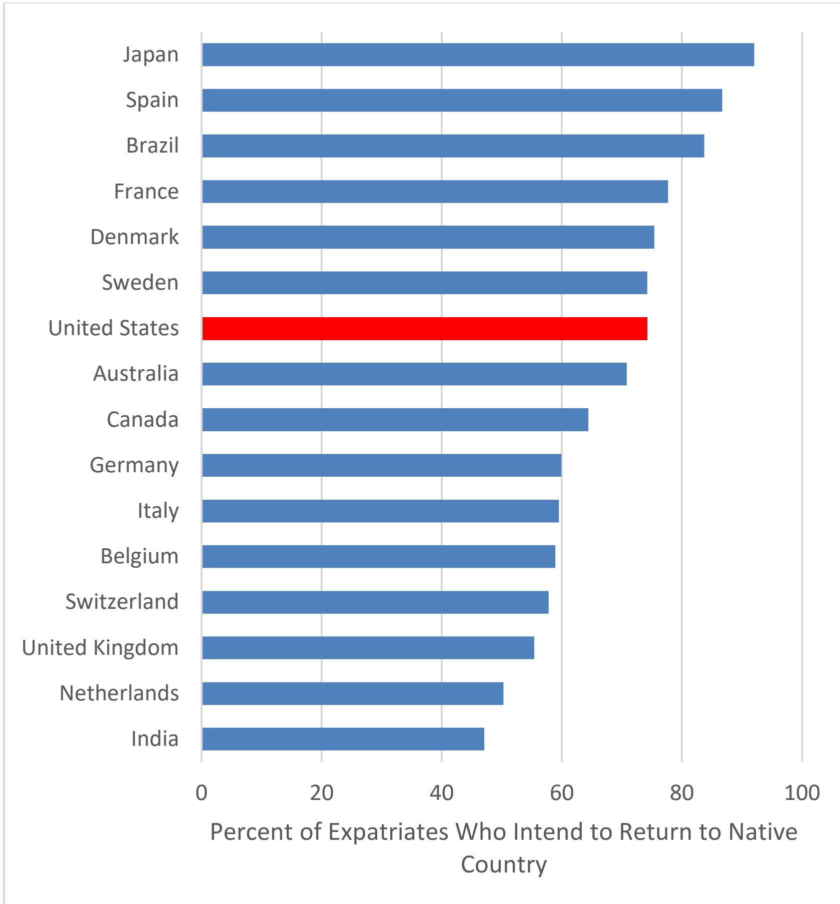
[16] OECD Occupational Sub-major Group 21: "Science and engineering professionals conduct research; improve or develop concepts, theories and operational methods; or apply scientific knowledge relating to fields such as physics, astronomy, meteorology, chemistry, geophysics, geology, biology, ecology, pharmacology, medicine, mathematics, statistics, architecture, engineering, design and technology" (International Labour Organisation 2016).

However, many of the Americans reported to be STEM workers overseas are likely not permanent expatriates. Based on responses to a 2011 survey of authors in STEM journals, Franzoni et al. (2012) found that U.S.-native respondents were the second least likely nationality to be working outside their home country (only 5% were outside the United States; Figure 24) and among the more likely planning to return home (74.2% of U.S. natives reported the intention to return home, compared to a median value of 67.6%; Figure 25). These results indicate that relatively few U.S.-native STEM workers leave the United States, and when they do, it is not long term. Rather, many American STEM workers overseas are likely visiting researchers, post-docs at overseas research institutions, and technical staff of U.S. companies assigned to overseas projects or offices.



Source: Franzoni et al. (2012)

Figure 24. Proportion of GlobSci Survey Respondents Outside Their Native Country at the Time of the Survey



Source: Franzoni et al. (2012)

Figure 25. Proportion of GlobSci Survey Respondents Outside Their Native Country Who Intend to Return

6. Factors Influencing the Loss of STEM Talent from the United States

The loss of STEM talent from the United States represents the cumulative effect of numerous individual decisions balancing personal, cultural, professional, family, and economic factors. Overall, STEM students and workers report that they choose to come to and stay in the United States primarily for the educational, research, and professional opportunities, whereas those who leave tend to cite family and cultural factors (Van Noorden 2012; Klimaviciute 2017). Although every decision to stay or leave is individual, each is made in the context of U.S. immigration and naturalization policy, the capacity of the U.S. STEM economy to absorb STEM talent, and the efforts of other countries to attract STEM talent.

A. Obstacles to Immigration and Naturalization

One of the most widely cited reasons driving foreign STEM talent to leave the United States (and discouraging it from coming) is the country's difficult-to-navigate immigration and naturalization rules governing who can come and who can stay (Wasem 2012; Han et al. 2015; Klimaviciute 2017; Zwetsloot et al. 2019; Chen 2023). High refusal rates and quotas on highly skilled workers are one of the primary factors that lowered the U.S. global ranking from second to eighth place as an attractive destination for high-skilled immigrants among OECD countries (Dumont and Andersson 2023).

In the United States, employment-based temporary work visas and permanent resident applications require sponsorship by an employer, making businesses key gatekeepers for the entry of skilled migrants (Czaika 2018). In contrast, some other countries with large influxes of high-skilled migrants, like Australia and Canada, determine eligibility for work visas or immigration using a point system that favors migrants with a high level of education, language fluency, and skills in in-demand occupations (Czaika 2018). Although points-based systems make admission criteria less arbitrary from the perspective of a migrant, they can result in under-employment of foreign workers who were admitted based on their qualification but are unable to find work appropriate for their skill level (Czaika 2018).

Although the U.S. system requiring employer sponsorship is less likely to result in under-employment, it leads to different unintended negative consequences. Applying for a visa and obtaining employer sponsorship requires filling out complex paperwork and dealing with multiple Federal agencies that often requires the aid of an attorney specializing in immigration law. Larger companies with greater legal wherewithal have an advantage in supporting potential migrant employees and submitting successful LCAs. As a result, 40% of capped H-1B visas (i.e., not including academic institutions and nonprofit research institutes) went to just 30 employers in 2022 (Costa and Hira 2023). A study by Roach and Skrentny (2019) found that the lower percentage of foreign doctorate graduates working in startups compared to established firms can be partially explained by the greater likelihood of receiving visa sponsorship with the latter.

In addition to putting smaller employers at a disadvantage when hiring foreign workers, the rules governing H-1B visas also foster an "outsourcing" business model: 13 of the top 30 H-1B employers, representing 17,500 temporary workers, provide skilled labor on a temporary or contract basis to other companies. Because workers on H-1B visas depend on their sponsoring employer to remain in the United States, they have less agency in determining where they can work than U.S. citizens and permanent residents, and they cannot change jobs without finding an alternate sponsor (Costa 2017). Companies operating an outsourcing model also have little incentive to serve as sponsors for employment-based LPR applications.

Another obstacle that highly skilled foreign workers face in joining the U.S. STEM ecosystem as full participants is the cap on the number of temporary employment visas. For the 2024 approval year, USCIS received 781,000 registrations to be considered for an H-1B visa (Kumar 2023a, 2023b), indicating that 85% or more of new H-1B registrations for the 85,000 openings (not including those at universities and nonprofit research institutions) are not successful. It is important to note, however, that except for those transitioning to an H-1B visa from another visa status, failed H-1B applications represent the intensity of demand to come to the United States, not a loss of talent from the country. In addition, the number of registrations may be inflated due to fraudulent schemes to submit multiple submissions on the behalf of a single individual (Bailey et al. 2023). Kato and Sparber (2013) found that H-1B visa restrictions decreased the number of applicants to the United States from the top ability levels, and Shih (2016) found that after the implementation of H-1B visa caps in 2004, the number of international students from countries that did not have access to alternative work visas (H-1B1, TN and E-3 visas stemming from trade agreements that exempt citizens of Canada, Mexico, Chile, Singapore, and Australia from the H-1B cap) dropped compared to countries that did have access to these alternative visas.

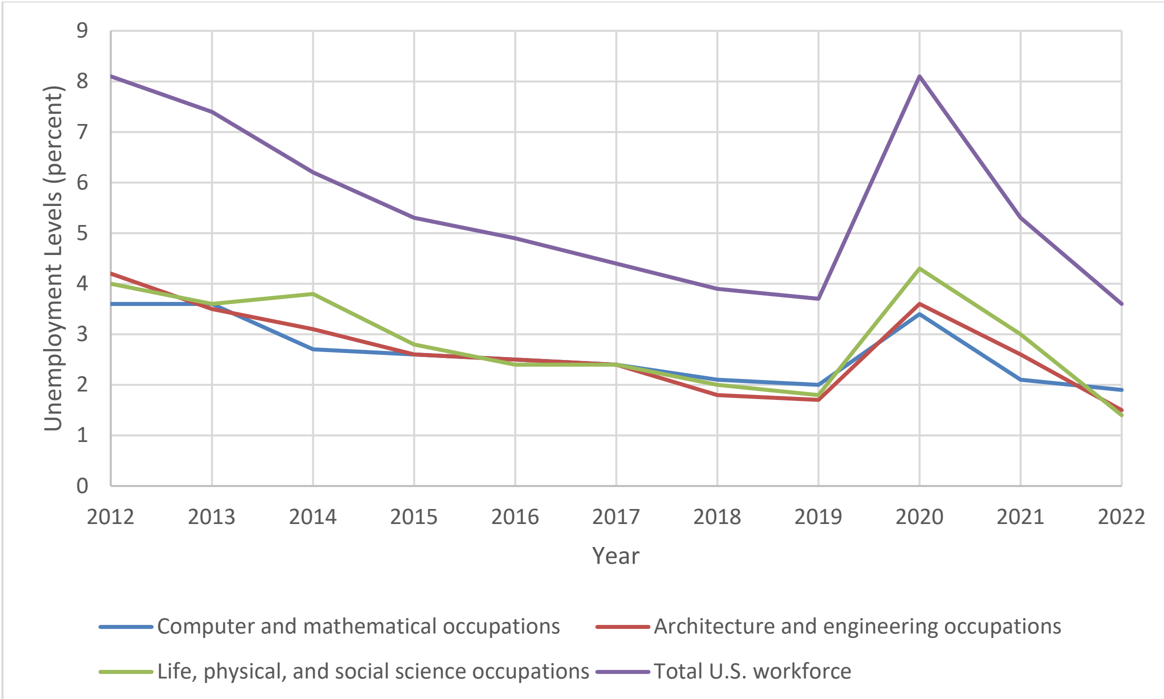
Caps on LPR approvals present a similar obstacle. In 2021, the cumulative backlog for employment-based green cards amounted to 1.4 million applicants who have a sponsor petition pending, have had their petition approved and have been waitlisted due to annual limits, or have filed an application for adjustment of status from a non-immigrant visa (Bier 2022). Country-based immigration caps are particularly detrimental to the stay rates of Chinese and Indian students, who make up a large portion of the foreign student population and often wait decades to obtain permanent residency (Kahn and MacGarvie 2018). Zwetsloot et al. (2019) found that for each year of delay in waiting for a green card, the percentage of Chinese and Indian graduates remaining in the United States drops by several points, and Bier (2019) found that wait times for high-skilled workers from China range from 6 to 16 years and from India from 8 to over 50 years (for EB-2 workers). And although foreign workers can remain in the United States after the expiration of an H-1B visa if they have applied for LPR status, they remain restricted to the employment and other conditions defined by their temporary work visa.

The expense of obtaining a work visa or green card, the slim chance of receiving a temporary work visa (and the inability to switch employers without getting reapproved), and the long waits to obtain LPR status can discourage foreign STEM talent from coming to the United States and drive foreign STEM talent to leave. The difficulty of immigration and naturalization to the United States appears to be a stronger discouraging factor for workers than international students, who indicated difficulties in immigration as a secondary factor relative to personal, cultural, and family reasons for returning to their home countries.

B. Employment Capacity of the U.S. STEM Economy

Over the past decade and longer, numerous reports and commentaries from academia, government, and industry have warned that the United States is in danger of experiencing a critical shortage of STEM workers (PCAST 2012; NASEM 2016; NSB 2019; Hira et al. 2014; Tang 2022; Knox 2023), although others have questioned the basis this claim (Teitelbaum 2014, 2019; Charette 2013; Abraham 2015; Camilli and Hira 2018). Recruiting foreign STEM workers could be a critical component of filling a gap in STEM talent and would stimulate growth of the U.S. economy (Connan 2022), but if the U.S. STEM economy does not have the capacity to absorb an influx of talent, then foreign workers may choose or be forced to leave the country.

From 2012 to 2022, unemployment rates in computer and mathematical occupations, architecture and engineering occupations, and life, physical, and social science occupations dropped from 4% to 2% (with the exception of sharp COVID-driven increases in 2020 and 2021), suggesting a tightening labor market for STEM workers over the past decade (Figure 26). However, during this time period, unemployment rates in STEM occupations have consistently been about half that of the overall U.S. unemployment rate, indicating that the increase in demand for STEM talent also reflects broader economic and employment trends.

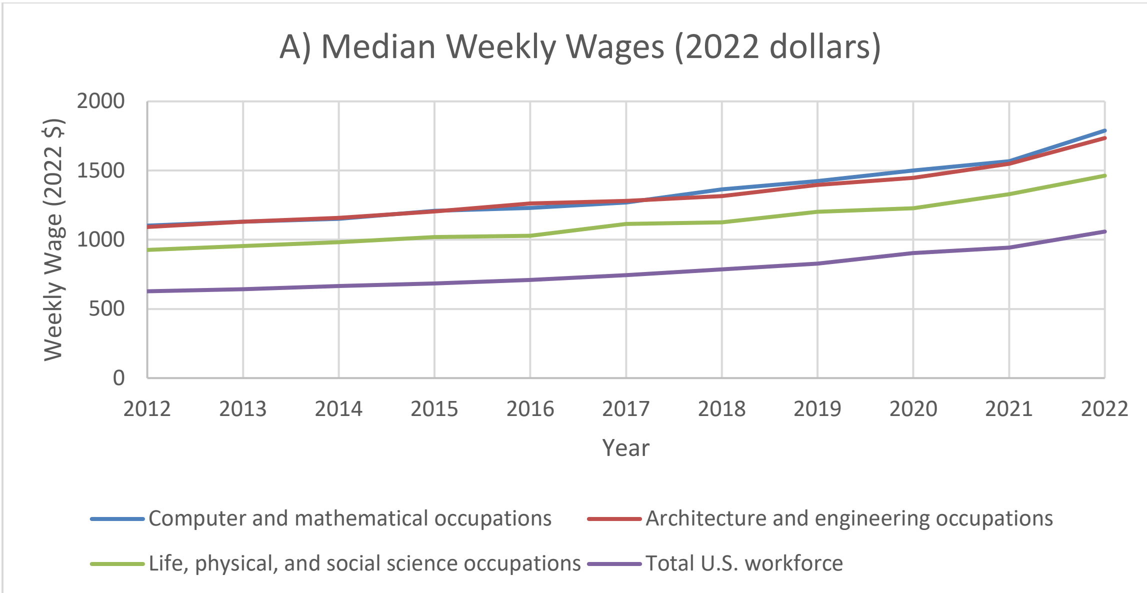


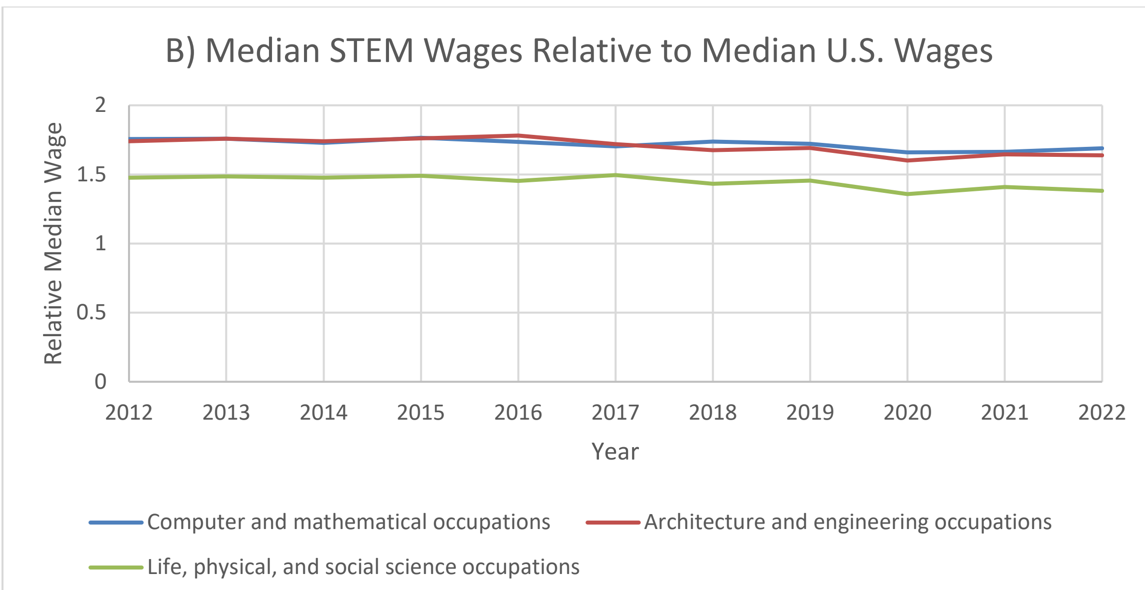
Note: Data available in Appendix Table D-7.

Figure 26. Annual Unemployment Levels for STEM Occupations 2012–2022

Data on wages over the same period show a pattern consistent with unemployment rates. Between 2012 and 2022, median wages in STEM occupations have consistently risen in real dollars and remained 50% to 75% higher than the overall U.S. median wage, suggesting increasing demand for STEM workers (Figure 27A). However, when scaled to the overall U.S. median wage, STEM wages show a decrease of 4% to 6% between 2012 and 2022 (Figure 27B), indicating that the intensity of demand for STEM workers has not increased and may even have declined slightly over the past decade (Hira 2022).

Numerous authors (e.g., Charette 2013; Xue and Larson 2015; Salzman and Benderly 2019) have noted that a substantial majority of people who graduated with a bachelor's degree in STEM do not work in a STEM occupation (62% according to U.S. Census Bureau data [Day and Martinez 2021]), although many work in STEM-adjacent occupations like STEM educators or managers and supervisors of STEM workers (Salzman and Benderly 2019).





Note: Data available in Appendix Table D-8.

Figure 27. Median Wage Levels for STEM Occupations 2012–2022

It is important to acknowledge, however, that such overall figures for broadly defined occupational categories can mask imbalances in supply and demand for particular STEM disciplines, economic sectors, and skill levels. Some occupational sectors have consistently experienced far more supply than demand for workers. For example, the number of STEM doctoral degrees awarded in the United States annually far exceeds the number of university faculty positions that come available each year (Xue and Larson 2015), leaving many doctoral graduates unable to fulfill ambitions to become professors. Jobs in the biomedical field have also experienced an oversupply since the 1970s (Mason et al. 2016).

Shortages in STEM talent often reflect rapid growth of an economic sector. Xue and Larson (2015) identified periods of talent shortages in information technology and petroleum engineering that reflect the boom-and-bust nature of these sectors. They also found that the aerospace sector had difficulty filling vacancies for mechanical, systems, and aerospace engineers, but in this case, the need to be a U.S. citizen in order to get a clearance to work on technologies with applications for national security may be acting as a barrier to foreign temporary workers, thereby cutting a large portion of supply out of consideration. Similarly, Xue and Larson (2015) found evidence of unmet demand within the Department of Defense for electrical, systems, and nuclear engineers, quantitative psychologists, and physicists with advanced degrees. Again, this may reflect a citizenship requirement to obtain a security clearance, but it also likely reflects salary caps that make U.S. Government compensation less appealing than the higher salaries in the private sector.

Foreign STEM talent makes up a sizable share of the overall STEM workforce and is critical to the health of the U.S. STEM ecosystem. However, overall wage and unemployment data for STEM occupations in the United States suggest an ample supply of talent, with the exception of specific sectors responding to rapidly changing economic conditions. Temporary foreign workers are lost from the U.S. STEM ecosystem if they cannot find employment, but from an economic and employment vantage point, the departure of unemployable talent may not strictly represent a loss. However, such outflows of talent—particularly scientists and engineers who benefited from education and training in this country—do represent a potential boon for America's international competitors, who can benefit from their skills and knowledge.

C. Recruitment Efforts by Other Nations

To compete for globally mobile STEM talent, many nations have established programs to attract scientists and engineers (Table 6). Some of these focus on repatriating those who left their home country to study or work elsewhere, whereas others seek to draw foreign talent to enhance the country's STEM capacity. In addition, different programs aim at different levels of experience: students, entrepreneurs, professionals, or academics.

Table 6. Programs to Attract High-Skilled Talent Outside the United States

Country	Program Name	Website	Program Description
Argentina	R@ICES	raices.mincyt.gov.ar	The RAICES awards are intended for Argentine scientists, researchers and technologists who reside abroad and actively collaborate with the strengthening of the National System of Science, Technology and Innovation.
Brazil	Science Without Borders "Young Talent Program" (i.e., Jovens Talentos)	cienciasemfronteiras.gov.br	Among other goals, the program seeks to attract researchers from abroad who want to settle in Brazil or establish partnerships with Brazilian researchers in the priority areas defined in the Program.
Canada	H-1B visa holder work permit	canada.ca/en/immigration-refugees-citizenship/services/work-canada/permit/h1b.html	A 2023 program intended to attract anyone with a valid H-1B Specialty Occupations visa living in the United States. Cap of 10,000 applications was reached in days. It is unknown how many applicants moved to Canada or whether the program will be opening in the future.
Chile	Start-up Chile	startupchile.org	Program to attract early stage entrepreneurs to build their startup companies in Chile.
China	High-End Foreign Expert Recruitment Plan (formerly the 1000 Talents Program)	most.gov.cn	The program aims to repatriate Chinese business and technical talent and to attract non-Chinese talent.
Germany	German Academic International Network (GAIN)	gain-network.org	A network of scientists and researchers of all disciplines from Germany, working at leading research institutions worldwide with special focus on the United States and Canada. GAIN helps its members maintain and build their international networks and facilitates transatlantic mobility and cooperation.

Country	Program Name	Website	Program Description
Israel	Gvahim	gvahim.org.il	A nonprofit organization dedicated to facilitating the successful integration of Olim (members of the Jewish diaspora immigrating to Israel) into the Israeli labor market.
Spain	Spanish Ramón y Cajal Program	euraxess.ec.europa.eu	The program provides financial support for a period of 5 years for the recruitment of PhD researchers.

Note: Modified from Han et al. (2015)

Many other countries have recognized the benefits of hosting international students (Connan 2022), including building international goodwill, supporting a valuable economic service sector, ensuring that academic programs have sufficient enrollments, expanding the pool of talent that can sustain a nation's workforce, and enabling novel research collaborations. In terms of attractiveness to international students, the OECD ranks Germany, the United Kingdom, Norway, and Australia as the top non-U.S. countries (Dumont and Andersson 2023). The most common destinations for international students after the United States include the United Kingdom, Canada, France, Australia, and Russia (Project Atlas 2022). Project Atlas (2022) reports that China was the eighth-most-common host country (it hosted 492,000 international students in 2018) thanks to a deliberate effort to expand its international student population in recent years, with a particular focus on attracting students from Africa (NAFSA 2020). Meanwhile, enrollments of all international students at U.S. institutions peaked in 2015–2016 and have dropped slightly since then (NAFSA 2020), although the number of international students in STEM disciplines has continued to increase since 2016.

An important aspect of a nation's attractiveness to international students is the opportunity to work in the host country after graduation (NAFSA 2020; Connan 2022). Post-study work visas in many countries are comparable to the U.S. OPT program. For example, Australia provides post-study work visas valid for 2 to 4 years, and Canada allows international students to work for up to 3 years after getting a Canadian degree. However, unlike the United States, post-study work explicitly increases an immigrant's value toward permanent residency in the points-based approval system used by those two countries (Zwetsloot et al. 2018).

Many overseas universities seek to recruit top academic talent for their faculties from around the world. In some cases, this is accomplished simply by casting an international net when posting and disseminating academic job announcements. In other cases, countries offer prestigious fellowships and other special incentives for international scholars. For example, Australia offers up to 17 Laureate Fellowships per year, which aim to attract and retain "outstanding researchers and research leaders of international reputation." The 5-year award provides funding for a professor-level salary, two post-doctoral fellows for 5 years, two postgraduate research students for 4 years, and up to $300,000 per year of project funding (Australian Research Council 2023a). Although the Laureate Fellowship can be used to attract international researchers, in 2023, only 9 of 119 applications were from foreign nationals or returning Australians and all awards went to resident Australians (Australian Research Council 2023b).

Another widely cited program to attract foreign talent is China's High-End Foreign Expert Recruitment Plan (HEFERP), which was established in 2019 and absorbed the more widely known Thousand Talents Program, which aimed to recruit STEM academics and entrepreneurs from abroad (Weinstein 2023). By early 2020, 12 years after it was established, the Thousand Talents Program and its successor are estimated to have recruited around 10,000 scientists attracted by generous salaries and abundant research funding and resources (Barry and Kolata 2020).

Nevertheless, the balance of flow of Chinese STEM talent is substantially in the United States' favor. In the 2018–2019 academic year, Feldgoise and Zwetsloot (2020) estimated that there were 40,473 Chinese doctoral STEM students enrolled at U.S. universities (80% of Thousand Talent Program participants are estimated to have a doctoral degree; Sharma 2013). The 5- to 10-year stay rate for Chinese STEM doctoral students over the past two decades is estimated to be 85% to 90% (Finn and Pennington 2018; Corrigan et al. 2022), indicating that a much higher number of highly trained scholars from China choose to stay in the United States than have been drawn back by the HEFERP. In addition, although numerous international scholars have participated in the Thousand Talents Program and its successor since 2008, many maintain affiliations with their home institutions outside of China and only spend limited time in China—i.e., the program has had mixed results as a means of fully repatriating Chinese talent or encouraging immigration of foreign talent (Sharma 2013).

Although the flow of talent between the United States and the world is largely in the United States' favor, it is important to acknowledge concerns that researcher and laboratory exchange can serve as a conduit for knowledge or technology that is economically valuable or has national security sensitivities to the nation's competitors and adversaries. In addition, foreign funding of American research can be used to gain access to U.S. knowledge and technology as well as to foster goodwill. Some prominent U.S. scientists who have not disclosed joint affiliations and financial support from China have faced academic discipline and even criminal charges for not being forthcoming about their relationships with foreign funding agencies (Barry and Kolata 2020). U.S. research security policy aims to balance the benefits of international scientific collaboration and exchange for the U.S. STEM enterprise with the need to hold sensitive knowledge and technology close (NSTC 2022).

7. Summary and Conclusions

This report uses Federal and other data sources to address Recommendation 2 of the 2022 NSTC ISTC Report:

> *Conduct research to understand why STEM talent leaves the United States or chooses to go to other countries, including examining the entire innovation pipeline to identify research, development, regulatory, statutory, capacity, and infrastructure challenges to STEM talent recruitment and retention.*

To characterize the loss of STEM talent from the United States, a conceptual model of the U.S. STEM ecosystem was constructed (Figure 1). The model serves as a framework for identifying where data about talent flowing through the U.S. STEM ecosystem are available and where gaps in information and understanding remain. Using publicly available data from Federal agencies, including NSF, BLS, U.S. Census Bureau, and USCIS, the magnitude of talent pools and flows in the U.S. STEM ecosystem were estimated (Table 7).

Table 7. Estimated Gains and Losses of International Talent in the U.S. STEM Ecosystem

Students (based on degree completions in 2021)	
International students lost upon graduation (104,000 grads)	-27,000 to -29,000
Doctoral (14,000 grads)	-2,000
Master's (60,000 grads)	-7,000
Bachelor's (30,000 grads)	-20,500
International students eventually lost from U.S. workforce based on number that obtain a temporary worker or other visa	-70,800
Post-Doctoral Scholars	
Long-term loss of U.S.-trained doctoral graduates	-2,800 to -3,500
Number of post-docs recruited from non-U.S. institutions	+2,500 to +3,500
Workers	
Total STEM workers obtaining H-1B visa	+82,000 to +112,000
Number of STEM workers not transitioning from international student status (net import gain)	+55,000 to +75,000
Number of STEM workers gaining employment-based lawful permanent resident status	+80,000 to +88,000

Based on comparisons of the number of graduates in STEM disciplines from U.S. institutions of higher education with data on the number of visa status changes from student to temporary worker, roughly 68% of international STEM graduates leave the United States each year. Limited information on degree level and STEM discipline in the visa data prevents a more refined characterization of the loss of STEM talent. However, information on immediate post-graduation stay rates indicates that international students earning graduate degrees stay at much higher rates (85% for doctoral students and 89% for master's students) than those finishing bachelor's degrees (estimated at 38%; Tables 2 and 5), and long-term stay rates for international STEM doctoral students completing a degree in the United States are around 75% (Finn and Pennington 2018; Corrigan et al. 2022), amounting to an annual loss of around 2,800 to 3,500. This is balanced, however, by the 2,500 to 3,500 foreign-trained post-doctoral scholars who come to the United States from overseas each year.

Since 2012, between 82,000 and 112,000 international STEM workers were approved for new temporary worker visas each year (Figure 18). Since around 38,000 of these visas represent international students transitioning from student visa status each year, this means that between 55,000 to 75,000 foreign STEM workers have been added to the U.S. labor force annually over the past decade. Temporary worker visas only allow foreign workers to stay in the United States for a certain number of years. Joining the U.S. STEM workforce permanently requires obtaining lawful permanent residency. Data on the number of workers on H-1B and other employment visas who leave the United States annually could not be found, but a rough estimate of the number of high-skilled STEM workers who obtain employment-based permanent residency annually is 80,000 to 88,000. It is worth noting that not all immigrants with LPR status choose to stay in the United States, as documented by Wadhwa et al. (2009).

However, many foreign STEM workers can spend years in limbo waiting for their green card petition to be approved; during this time, they do not have the same rights and privileges as citizens and permanent residents and are vulnerable to exploitation by employers. In addition, the wait times for workers from different countries are not distributed equitably, with migrants from China and India facing waits of years to decades.

Data on the loss of native-born STEM talent are sparse for both students and workers, but what information is available suggests that relatively few Americans with college or higher degrees or training in STEM occupations choose to emigrate. In addition, those who choose to study or work overseas generally do so with the intention to return.

Ultimately, most of the STEM talent flowing out of the United States appears to be international students graduating with bachelor's degrees rather than more highly trained graduate students and more experienced high-skilled STEM workers (Table 7). The reasons that STEM talent seeks to stay in the United States—primarily motivated by professional, educational, and economic opportunities—are largely the same as those that initially attracted them. Those who choose to leave—both students and workers—more commonly cite personal, cultural, and family reasons. However, high-skilled talent is increasingly globally mobile, with countries vying to attract migrants who can contribute to their national economic, social, and scientific capacity. Although the United States remains near the top of the rankings for attractiveness, international competition for STEM talent increases every year. The primary concern around foreign programs recruiting talent from the United States is the prospect of international competitors and adversaries accessing skills and knowledge of high economic or security value. As a destination for STEM talent, the United States benefits from its highly ranked system of higher education, research freedom, and extensive research infrastructure, but these are areas that international competitors are investing in and modeling after the United States. As a destination for high-skilled foreign talent, the United States benefits from its long history as a nation of immigrants, but it suffers from having a weaker social services fabric than other appealing countries.

The work presented here, which draws on publicly available Federal data sources, illuminates important data gaps and opportunities for future research relevant to attracting and retaining highly skilled STEM talent, both native and foreign born, in the United States. One substantial ambiguity arises from inconsistency in the academic disciplines and occupations that are counted as STEM by different Federal agencies, making comparisons across data sets uncertain. In addition, some Federal data sets do not distinguish STEM from non-STEM occupations or even break out STEM as a whole, limiting the ability to document differences in recruitment and retention among different STEM fields. Lastly, the nationalities of students, workers, and visa holder are not always reported, limiting the ability to understand the flows of STEM talent to and from individual countries.

Future research into the attraction, retention, and loss of STEM talent will require more consistent and coordinated data reporting by Federal agencies on STEM education, immigration, and workforce to develop a fully integrated understanding of the flows of talent through the U.S. STEM ecosystem. More refined data on STEM occupation, STEM degree, national origin, visa status, and other factors would allow cross-analysis of different populations and sectors of the U.S. STEM ecosystem that would provide insight into the magnitude and motivation of loss as well as potential policy interventions to prevent it. In addition, long-term longitudinal tracking of individuals and cohorts would allow better estimates of stay rates and allow them to be related to other critical factors motivating STEM talent to leave the United States. Lastly, incorporating the paths of U.S. citizens and permanent residents through the U.S. STEM ecosystem is vital for understanding the role of immigrant STEM talent in meeting workforce demand. A conceptual model such as the one developed in this document (Figure 1) can provide a framework to organize the full array of varied information needed to characterize the U.S. STEM ecosystem and pose tractable questions about the flows of STEM talent into and out of the United States.

Appendix A.
World University Rankings 2023 for Science and Engineering[17]

Table A-1. Overall Rankings

Rank	Name	Country/Region	International Students
1	University of Oxford	United Kingdom	42%
2	Harvard University	United States	25%
3.5	University of Cambridge	United Kingdom	39%
3.5	Stanford University	United States	24%
5	Massachusetts Institute of Technology	United States	33%
6	California Institute of Technology	United States	34%
7	Princeton University	United States	23%
8	University of California, Berkeley	United States	24%
9	Yale University	United States	21%
10	Imperial College London	United Kingdom	61%
11.5	Columbia University	United States	38%
11.5	ETH Zurich	Switzerland	41%
13	The University of Chicago	United States	36%
14	University of Pennsylvania	United States	23%
15	Johns Hopkins University	United States	29%
16	Tsinghua University	China	10%
17	Peking University	China	19%
18	University of Toronto	Canada	26%
19	National University of Singapore	Singapore	25%

[17] All appendix data tables are available in an Excel spreadsheet file accompanying this report.

Rank	Name	Country/Region	International Students
20	Cornell University	United States	26%
21	University of California, Los Angeles	United States	16%
22	UCL (University College London)	United Kingdom	60%
23	University of Michigan-Ann Arbor	United States	17%
24	New York University	United States	42%
25	Duke University	United States	24%

Source: https://www.timeshighereducation.com/world-university-rankings/2023/world-ranking

Note: Unshaded rows indicate U.S. institutions.

Table A-2. Computer Sciences Rankings

Rank	Name	Country/Region	International Students
1	University of Oxford	United Kingdom	42%
2	Massachusetts Institute of Technology	United States	33%
3	Stanford University	United States	24%
4	ETH Zurich	Switzerland	41%
5	Carnegie Mellon University	United States	47%
6	University of Cambridge	United Kingdom	39%
7	National University of Singapore	Singapore	25%
8	University of California, Berkeley	United States	24%
9	Harvard University	United States	25%
10	Technical University of Munich	Germany	36%
11.5	Imperial College London	United Kingdom	61%
11.5	Princeton University	United States	23%
13	Tsinghua University	China	10%
14	Nanyang Technological University, Singapore	Singapore	25%
15	University of Washington	United States	18%
16	Cornell University	United States	26%
17	Georgia Institute of Technology	United States	40%
18	University of Illinois at Urbana-Champaign	United States	22%
19	California Institute of Technology	United States	34%
20	Peking University	China	19%
21	Columbia University	United States	38%
22.5	École Polytechnique Fédérale de Lausanne	Switzerland	62%
22.5	University of Toronto	Canada	26%
24	University of Edinburgh	United Kingdom	47%
25	New York University	United States	42%

Source: https://www.timeshighereducation.com/world-university-rankings/2023/subject-ranking/computer-science

Table A-3. Engineering Rankings

Rank	Name	Country/Region	International Students
1	Harvard University	United States	25%
2	Stanford University	United States	24%
3	University of California, Berkeley	United States	24%
4	Massachusetts Institute of Technology	United States	33%
5	University of Oxford	United Kingdom	42%
6	California Institute of Technology	United States	34%
7	University of Cambridge	United Kingdom	39%
8	National University of Singapore	Singapore	25%
9	Princeton University	United States	23%
10	ETH Zurich	Switzerland	41%
11	Georgia Institute of Technology	United States	40%
12	Peking University	China	19%
13	Nanyang Technological University, Singapore	Singapore	25%
14	Imperial College London	United Kingdom	61%
15	Tsinghua University	China	10%
16	University of California, Los Angeles	United States	16%
17	Yale University	United States	21%
18	University of Michigan-Ann Arbor	United States	17%
19	École Polytechnique Fédérale de Lausanne	Switzerland	62%
20	Technical University of Munich	Germany	36%
21	Delft University of Technology	Netherlands	31%
22	Carnegie Mellon University	United States	47%
23	University of Texas at Austin	United States	10%
24	Cornell University	United States	26%
25	Columbia University	United States	38%

Source: https://www.timeshighereducation.com/world-university-rankings/2023/subject-ranking/engineering-and-it

Table A-4. Life Sciences Rankings

Rank	Name	Country/Region	International Students
1	Harvard University	United States	25%
2	University of Cambridge	United Kingdom	39%
3	Massachusetts Institute of Technology	United States	33%
4	University of Oxford	United Kingdom	42%
5	Stanford University	United States	24%
6	California Institute of Technology	United States	34%
7	Yale University	United States	21%
8	Princeton University	United States	23%
9	University of California, Berkeley	United States	24%
10	Johns Hopkins University	United States	29%
11	Tsinghua University	China	10%
12	Columbia University	United States	38%
13	ETH Zurich	Switzerland	41%
14	Imperial College London	United Kingdom	61%
15	University of California, San Diego	United States	28%
16	University of Washington	United States	18%
17	The University of Chicago	United States	36%
18	Peking University	China	19%
19	Cornell University	United States	26%
20	Wageningen University & Research	Netherlands	27%
21	University of Pennsylvania	United States	23%
22	UCL (University College London)	United Kingdom	60%
23	National University of Singapore	Singapore	25%
24.5	University of California, Los Angeles	United States	16%
24.5	University of Toronto	Canada	26%

Source: https://www.timeshighereducation.com/world-university-rankings/2023/subject-ranking/life-sciences

Table A-5. Physical Sciences Rankings

Rank	Name	Country/Region	International Students
1	Princeton University	United States	23%
2.5	University of California, Berkeley	United States	24%
2.5	Massachusetts Institute of Technology	United States	33%
4	California Institute of Technology	United States	34%
5	Stanford University	United States	24%
6	Harvard University	United States	25%
7	University of Cambridge	United Kingdom	39%
8	University of Oxford	United Kingdom	42%
9	ETH Zurich	Switzerland	41%
10	Columbia University	United States	38%
11	The University of Chicago	United States	36%
12	Yale University	United States	21%
13	Imperial College London	United Kingdom	61%
14	National University of Singapore	Singapore	25%
15	University of California, Los Angeles	United States	16%
16	Peking University	China	19%
17	Cornell University	United States	26%
18	Tsinghua University	China	10%
19	University of Washington	United States	18%
20	Paris Sciences et Lettres – PSL Research University Paris	France	22%
21	École Polytechnique Fédérale de Lausanne	Switzerland	62%
22	University of Toronto	Canada	26%
23	Technical University of Munich	Germany	36%
24	University of Michigan-Ann Arbor	United States	17%
25	Fudan University	China	9%

Source: https://www.timeshighereducation.com/world-university-rankings/2023/subject-ranking/physical-sciences

Appendix B.
STEM Degree Completions

Table B-1. Total Number of Students Completing a Bachelor's Degree in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	13,085	68,894	22,017	69,309	12,413	17,517	203,235
2013	13,641	71,915	23,931	72,804	13,574	18,422	214,287
2014	14,174	74,929	29,428	78,173	14,121	19,216	230,041
2015	14,915	78,732	33,578	83,460	15,043	19,657	245,385
2016	15,217	81,589	38,491	90,480	15,846	20,159	261,782
2017	15,370	83,130	43,612	98,083	17,057	20,620	277,872
2018	15,597	85,337	50,059	103,013	18,225	21,115	293,346
2019	15,787	87,914	56,726	107,118	19,072	20,955	307,572
2020	16,610	93,454	64,938	110,764	20,568	21,323	327,657
2021	16,726	98,395	70,594	109,064	20,623	20,498	335,900

Source: IPEDS, National Center for Education Statistics, Statistical Tables for 2012 through 2021. Searched "Number of students receiving awards/degrees, by race/ethnicity and gender". Including variables: Completions – Awards/degrees conferred by program (2020 CIP classification), award level, race/ethnicity, and gender – CIP codes: 01. Agricultural/Animal/Plant/Veterinary Science and Related Fields; 11. Computer and Information Sciences and Support Services; 14. Engineering; 26. Biological and Biomedical Sciences; 27. Mathematics and Statistics; 40. Physical Sciences – Award level: Bachelor's degree – Grand total.

https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1&sid=f19f670d-354d-4ae9-84e3-4ff6abc48e5d&rtid=3

Table B-2. Number of International Students Completing a Bachelor's Degree in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	202	1,985	1,416	5,588	1,292	711	11,194
2013	306	2,087	1,462	5,995	1,694	866	12,410
2014	341	1,983	1,871	6,691	2,001	918	13,805
2015	389	2,035	2,279	7,561	2,404	1,014	15,682
2016	398	2,319	2,894	8,839	2,919	1,125	18,494
2017	432	2,459	3,632	10,270	3,489	1,264	21,546
2018	480	2,748	4,685	11,394	3,693	1,410	24,410
2019	524	3,034	5,714	11,788	4,179	1,587	26,826
2020	627	3,218	7,211	12,321	4,996	1,717	30,090
2021	571	3,289	8,218	11,247	5,009	1,630	29,964

Source: IPEDS, National Center for Education Statistics, Statistical Tables for 2012 through 2021. Searched "Number of students receiving awards/degrees, by race/ethnicity and gender". Including variables: Completions – Awards/degrees conferred by program (2020 CIP classification), award level, race/ethnicity, and gender – CIP codes: 01. Agricultural/Animal/Plant/Veterinary Science and Related Fields; 11. Computer and Information Sciences and Support Services; 14. Engineering; 26. Biological and Biomedical Sciences; 27. Mathematics and Statistics; 40. Physical Sciences – Award level: Bachelor's degree –U.S. Nonresident total.

https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1&sid=f19f670d-354d-4ae9-84e3-4ff6abc48e5d&rtid=3

Table B-3. Percentage of U.S. Bachelor's Degree Completions in STEM Disciplines Awarded to International Students

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	1.54%	2.88%	6.43%	8.06%	10.41%	4.06%	5.51%
2013	2.24%	2.90%	6.11%	8.23%	12.48%	4.70%	5.79%
2014	2.41%	2.65%	6.36%	8.56%	14.17%	4.78%	6.00%
2015	2.61%	2.58%	6.79%	9.06%	15.98%	5.16%	6.39%
2016	2.62%	2.84%	7.52%	9.77%	18.42%	5.58%	7.06%
2017	2.81%	2.96%	8.33%	10.47%	20.45%	6.13%	7.75%
2018	3.08%	3.22%	9.36%	11.06%	20.26%	6.68%	8.32%
2019	3.32%	3.45%	10.07%	11.00%	21.91%	7.57%	8.72%
2020	3.77%	3.44%	11.10%	11.12%	24.29%	8.05%	9.18%
2021	3.41%	3.34%	11.64%	10.31%	24.29%	7.95%	8.92%

International and Total STEM Master's Degree Completions

Table B-4. Total Number of Students Completing a Master's Degree in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	2,429	10,609	16,560	37,149	5,596	6,382	78,725
2013	2,449	11,370	17,831	37,314	6,182	6,490	81,636
2014	2,525	12,082	19,469	39,984	6,591	6,474	87,125
2015	2,464	12,729	24,804	43,164	6,973	6,518	96,652
2016	2,653	13,742	30,932	47,195	7,753	6,488	108,763
2017	2,717	14,212	35,188	48,273	8,308	6,532	115,230
2018	2,624	15,054	37,352	48,161	9,576	6,607	119,374
2019	2,665	15,746	37,367	46,466	10,503	6,576	119,323
2020	2,880	16,164	42,491	45,044	11,163	6,478	124,220
2021	2,674	16,766	44,025	45,100	11,754	6,312	126,631

Source: IPEDS, National Center for Education Statistics, Statistical Tables for 2012 through 2021. Searched "Number of students receiving awards/degrees, by race/ethnicity and gender". Including variables: Completions – Awards/degrees conferred by program (2020 CIP classification), award level, race/ethnicity, and gender – CIP codes: 01. Agricultural/Animal/Plant/Veterinary Science and Related Fields; 11. Computer and Information Sciences and Support Services; 14. Engineering; 26. Biological and Biomedical Sciences; 27. Mathematics and Statistics; 40. Physical Sciences – Award level: Master's degree – Grand total.

https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1&sid=f19f670d-354d-4ae9-84e3-4ff6abc48e5d&rtid=3

Table B-5. Number of International Students Completing a Master's Degree in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	545	1,909	8,197	15,565	2,365	1,823	30,404
2013	573	1,969	8,898	16,274	2,837	1,800	32,351
2014	582	2,061	10,057	18,365	3,266	1,855	36,186
2015	591	2,221	14,737	22,191	3,562	1,931	45,233
2016	619	2,260	20,222	26,551	4,308	1,936	55,896
2017	688	2,347	23,285	27,296	4,843	2,017	60,476
2018	630	2,440	24,517	26,392	5,863	1,929	61,771
2019	617	2,489	22,887	24,209	6,370	1,780	58,352
2020	672	2,648	25,998	22,401	6,575	1,856	60,150
2021	531	2,715	25,404	21,771	6,757	1,747	58,925

Source: IPEDS, National Center for Education Statistics, Statistical Tables for 2012 through 2021. Searched "Number of students receiving awards/degrees, by race/ethnicity and gender". Including variables: Completions – Awards/degrees conferred by program (2020 CIP classification), award level, race/ethnicity, and gender – CIP codes: 01. Agricultural/Animal/Plant/Veterinary Science and Related Fields; 11. Computer and Information Sciences and Support Services; 14. Engineering; 26. Biological and Biomedical Sciences; 27. Mathematics and Statistics; 40. Physical Sciences – Award level: Master's degree – U.S. Nonresident total.

https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1&sid=f19f670d-354d-4ae9-84e3-4ff6abc48e5d&rtid=3

Table B-6. Percentage of U.S. Master's Degree Completions in STEM Disciplines Awarded to International Students

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	22.44%	17.99%	49.50%	41.90%	42.26%	28.56%	38.62%
2013	23.40%	17.32%	49.90%	43.61%	45.89%	27.73%	39.63%
2014	23.05%	17.06%	51.66%	45.93%	49.55%	28.65%	41.53%
2015	23.99%	17.45%	59.41%	51.41%	51.08%	29.63%	46.80%
2016	23.33%	16.45%	65.38%	56.26%	55.57%	29.84%	51.39%
2017	25.32%	16.51%	66.17%	56.55%	58.29%	30.88%	52.48%
2018	24.01%	16.21%	65.64%	54.80%	61.23%	29.20%	51.75%
2019	23.15%	15.81%	61.25%	52.10%	60.65%	27.07%	48.90%
2020	23.33%	16.38%	61.18%	49.73%	58.90%	28.65%	48.42%
2021	19.86%	16.19%	57.70%	48.27%	57.49%	27.68%	46.53%

International and Total STEM Doctoral Degree Completions

Table B-7. Total Number of Students Completing a Doctoral Degree in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	725	7,769	1,659	8,583	1,646	5,332	25,714
2013	791	7,821	1,761	9,215	1,796	5,477	26,861
2014	799	8,287	1,898	9,905	1,845	5,768	28,502
2015	856	8,019	1,920	10,080	1,780	5,765	28,420
2016	817	7,895	1,920	10,128	1,836	5,996	28,592
2017	883	8,027	1,915	10,245	1,914	5,965	28,949
2018	849	8,204	1,959	10,660	1,991	6,123	29,786
2019	918	7,972	2,142	11,023	1,984	6,251	30,290
2020	1,012	7,968	2,373	11,183	2,028	5,988	30,552
2021	923	7,547	2,514	10,919	1,960	5,725	29,588

Source: IPEDS, National Center for Education Statistics, Statistical Tables for 2012 through 2021. Searched “Number of students receiving awards/degrees, by race/ethnicity and gender”. Including variables: Completions – Awards/degrees conferred by program (2020 CIP classification), award level, race/ethnicity, and gender – CIP codes: 01. Agricultural/Animal/Plant/Veterinary Science and Related Fields; 11. Computer and Information Sciences and Support Services; 14. Engineering; 26. Biological and Biomedical Sciences; 27. Mathematics and Statistics; 40. Physical Sciences – Award level: Doctor’s degree - research/scholarship – Grand total.

https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1&sid=f19f670d-354d-4ae9-84e3-4ff6abc48e5d&rtid=3

Table B-8. Number of International Students Completing a Doctoral Degree in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	387	2,054	843	4,787	799	2,135	11,005
2013	391	2,077	924	5,220	885	2,181	11,678
2014	410	2,253	1,027	5,545	898	2,394	12,527
2015	411	2,195	1,065	5,600	882	2,259	12,412
2016	420	2,087	1,101	5,624	855	2,381	12,468
2017	459	2,040	1,064	5,821	934	2,327	12,645
2018	441	2,052	1,142	6,145	986	2,418	13,184
2019	473	1,955	1,256	6,446	1,003	2,432	13,565
2020	535	2,038	1,400	6,737	1,109	2,336	14,155
2021	428	1,840	1,486	6,540	1,065	2,357	13,716

Source: IPEDS, National Center for Education Statistics, Statistical Tables for 2012 through 2021. Searched “Awards/degrees conferred by program (2020 CIP classification), award level, race/ethnicity, and gender” and “Awards/degrees conferred by program (2010 CIP classification), award level, race/ethnicity, and gender: 2009–10 to 2018–19”. Including variables: Completions – Awards/degrees conferred by program (2020 or 2010 CIP classification, as appropriate), award level, race/ethnicity, and gender – CIP codes: 01. Agricultural/Animal/Plant/Veterinary Science and Related Fields; 11. Computer and Information Sciences and Support Services; 14. Engineering; 26. Biological and Biomedical Sciences; 27. Mathematics and Statistics; 40. Physical Sciences – Award level: Doctor’s degree - research/scholarship – U.S. Nonresident total.

https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1&sid=f19f670d-354d-4ae9-84e3-4ff6abc48e5d&rtid=3

Table B-9. Percentage of U.S. Doctoral Degree Completions in STEM Disciplines Awarded to International Students

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	53.38%	26.44%	50.81%	55.77%	48.54%	40.04%	42.80%
2013	49.43%	26.56%	52.47%	56.65%	49.28%	39.82%	43.48%
2014	51.31%	27.19%	54.11%	55.98%	48.67%	41.50%	43.95%
2015	48.01%	27.37%	55.47%	55.56%	49.55%	39.18%	43.67%
2016	51.41%	26.43%	57.34%	55.53%	46.57%	39.71%	43.61%
2017	51.98%	25.41%	55.56%	56.82%	48.80%	39.01%	43.68%
2018	51.94%	25.01%	58.30%	57.65%	49.52%	39.49%	44.26%
2019	51.53%	24.52%	58.64%	58.48%	50.55%	38.91%	44.78%
2020	52.87%	25.58%	59.00%	60.24%	54.68%	39.01%	46.33%
2021	46.37%	24.38%	59.11%	59.90%	54.34%	41.17%	46.36%

Reported Post-Graduation Commitments of STEM Doctoral Students

Source: NSF SED https://ncses.nsf.gov/surveys/earned-doctorates/2021#survey-info

Table B-10. Post-Graduation Plans of Domestic Doctoral Students

Year	No Reported Commitment	Definite Commitment Reported	Reported Commitment Abroad	Reported Commitment in United States	Postdoctoral Research in United States	Academic Employment in United States	Industry Employment in United States	Other Commitment in United States	Unknown
2012	41.32%	58.68%	3.23%	55.44%	30.59%	6.59%	11.18%	4.39%	0.01%
2013	43.97%	56.03%	2.86%	53.13%	28.44%	6.60%	12.33%	4.46%	0.03%
2014	45.09%	54.91%	2.77%	51.93%	27.14%	7.41%	12.82%	4.56%	0.04%
2015	45.20%	54.80%	2.93%	51.66%	26.79%	7.13%	12.98%	4.76%	0.06%
2016	42.12%	57.88%	2.69%	55.12%	27.78%	6.99%	14.85%	5.50%	0.05%
2017	39.77%	60.23%	2.47%	57.76%	28.80%	7.92%	15.50%	5.55%	0.00%
2018	36.43%	63.57%	2.85%	60.70%	29.62%	8.12%	16.81%	6.16%	0.02%
2019	35.99%	64.01%	2.57%	61.43%	29.30%	7.61%	18.22%	6.29%	0.01%
2020	34.62%	65.38%	2.35%	63.02%	29.87%	7.53%	19.02%	6.60%	0.02%
2021	32.47%	67.53%	2.48%	65.04%	32.20%	7.09%	19.54%	6.21%	0.01%

Source: IPEDS, National Center for Education Statistics, Statistical Tables for 2012 through 2021. Searched “Awards/degrees conferred by program (2020 CIP classification), award level, race/ethnicity, and gender” and “Awards/degrees conferred by program (2010 CIP classification), award level, race/ethnicity, and gender: 2009–10 to 2018–19”. Including variables: Completions – Awards/degrees conferred by program (2020 or 2010 CIP classification, as appropriate), award level, race/ethnicity, and gender – CIP codes: 01. Agricultural/Animal/Plant/Veterinary Science and Related Fields; 11. Computer and Information Sciences and Support Services; 14. Engineering; 26. Biological and Biomedical Sciences; 27. Mathematics and Statistics; 40. Physical Sciences – Award level: Doctor’s degree - research/scholarship – U.S. Nonresident total.

https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1&sid=f19f670d-354d-4ae9-84e3-4ff6abc48e5d&rtid=3

Table B-11. Post-Graduation Plans of International Doctoral Students

Year	No Reported Commitment	Definite Commitment Reported	Reported Commitment Abroad	Reported Commitment in United States	Postdoctoral Research in United States	Academic Employment in United States	Industry Employment in United States	Other Commitment in United States	Unknown
2012	41.11%	58.89%	11.13%	47.74%	26.75%	3.26%	15.45%	0.85%	0.02%
2013	45.57%	54.43%	10.61%	43.76%	24.02%	3.17%	15.81%	0.55%	0.07%
2014	48.21%	51.79%	9.81%	42.10%	22.04%	3.28%	16.14%	0.65%	0.11%
2015	48.32%	51.68%	8.57%	43.08%	22.94%	3.44%	16.05%	0.64%	0.11%
2016	46.91%	53.09%	8.69%	44.62%	22.65%	3.58%	17.42%	0.97%	0.12%
2017	37.47%	62.53%	10.20%	52.30%	27.20%	4.18%	19.83%	1.10%	0.04%
2018	36.30%	63.70%	10.69%	52.99%	26.19%	3.93%	21.67%	1.21%	0.02%
2019	34.71%	65.29%	11.57%	53.60%	26.20%	3.91%	22.18%	1.30%	0.13%
2020	33.48%	66.52%	10.78%	55.70%	27.16%	3.82%	23.62%	1.10%	0.04%
2021	33.16%	66.84%	11.17%	55.55%	29.01%	3.36%	22.05%	1.12%	0.12%

Table B-12. OPT and STEM Extension Approvals

Year	OPT Approvals	STEM Extensions	STEM/OPT (1 year offset)
2003	87,323	–	–
2004	90,197	–	–
2005	86,821	–	–
2006	84,560	–	–
2007	80,402	–	1.2%
2008	81,372	927	7.2%
2009	85,004	5,894	12.3%
2010	86,494	10,415	15.2%
2011	92,187	13,167	18.0%
2012	98,710	16,625	19.4%
2013	104,155	19,103	21.1%
2014	113,389	21,974	24.8%
2015	136,069	28,077	33.1%
2016	157,374	44,995	36.9%
2017	165,459	58,037	32.8%
2018	145,785	54,352	48.1%
2019	155,146	70,067	33.8%
2020	135,228	52,442	41.9%
2021	121,301	56,727	47.7%
2022	128,886	57,910	–

Source: Data on the number of OPT and STEM extension approvals are included in the U.S. Custom and Immigration Services annual tabulation of Form I-765 Application for Employment Authorization. https://www.uscis.gov/sites/default/files/document/data/I-765_Application_for_Employment_FY03-21.pdf and https://www.uscis.gov/sites/default/files/document/data/I-765_Application_for_Employment_FY22.pdf

Table B-13. Number of Changes from F-1 to Other Nonimmigrant Visa Status 2008–2018

Year	F-1 to H-1B Visa Status Changes	F-1 to Other Temporary Work Visa Status Changes	F-1 to Other Nonimmigrant Visa Status Changes	Total Number of Changes from F-1 to Other Visa Status
2008	28,794	2,418	3,681	34,893
2009	29,722	1,773	4,083	35,578
2010	20,727	1,480	4,035	26,242
2011	28,906	1,482	3,658	34,046
2012	31,823	1,738	4,004	37,565
2013	30,558	2,252	3,363	36,173
2014	30,337	2,265	2,999	35,601
2015	29,947	2,401	3,236	35,584
2016	38,217	3,041	5,764	47,022
2017	33,343	3,159	4,169	40,671
2018	49,894	2,880	3,226	56,000

Source: Table 1 of U.S. Citizenship and Immigration Services, Office of Policy and Strategy Research and Evaluation Office. 2019. F-1 Students Obtaining Another Nonimmigrant Classification: Fiscal Year 2008–2018 Approvals. https://www.uscis.gov/sites/default/files/document/presentations/Report_-_F-1_Students_Obtaining_Another_Nonimmigrant_Classification.pdf

Table B-14. Number of Changes from F-1 and Other Student Visas to H-1B Status 2018–2023

Year	F-1 to H-1B Visa Status Changes	F-1 to O1A Visa Status Changes	F-2 to H-1B Visa Status Changes	H-4 to H-1B Visa Status Changes	J-1 to H-1B Visa Status Changes	Total Number of Changes from F-1 to Other Visa Status
2018	47,480	400	230	2,970	3,740	54,420
2019	68,260	680	230	4,780	4,200	77,470
2020	58,390	640	210	4,920	4,920	68,440
2021	58,720	700	250	5,650	4,890	69,510
2022	58,790	880	300	4,730	5,450	69,270
2023	40,050	1,360	270	4,330	6,030	50,680

Source: U.S. Citizenship and Immigration Services, Office of Policy and Strategy Research and Evaluation Office. 2023. Change of Status for Nonimmigrants: F-1, F-2, H-4, J-1, J-2 Fiscal Year 2018–2023. https://www.uscis.gov/sites/default/files/document/fact-sheets/change_of_status_factsheet_fy23.pdf

Appendix C.
Post-Doctoral Scholars in STEM

Table C-1. Number of International Post-Doctoral Scholars in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	575	11,680	463	4,365	446	5,208	22,737
2013	582	11,210	463	4,400	444	5,069	22,168
2014 (old)	670	10,975	513	4,503	524	5,105	22,290
2014 (new)	673	11,536	514	4,515	526	5,224	22,988
2015	764	11,792	569	5,135	618	5,582	24,460
2016	729	11,657	586	5,206	574	5,456	24,208
2017	596	11,662	568	5,189	547	5,342	23,904
2018	592	11,765	542	5,258	527	5,157	23,841
2019	640	12,290	565	5,577	590	5,427	25,089
2020	827	11,968	516	5,669	563	5,103	24,646
2021	812	11,040	530	5,433	551	4,882	23,248

Note: In 2014, NSF updated the survey frame following a comprehensive frame evaluation study that identified potentially eligible but not previously surveyed academic institutions in the United States with graduate in science, engineering, or health. A total of 151 newly eligible institutions were added, and two private for-profit institutions offering mostly practitioner-based graduate degrees were determined to be ineligible.

Source: 2017 through 2021: NSF NCSES. Survey of Graduate Students and Postdoctorates in Science and Engineering. Tables 2-2. Citizenship, ethnicity, and race of graduate students, postdoctoral appointees, and doctorate-holding nonfaculty researchers in science (engineering), by sex. Link for 2021 data: https://ncses.nsf.gov/pubs/nsf23312/table/5-3#section14012

2012 through 2016: Survey of Graduate Students and Postdoctorates in Science and Engineering Fall 2016. Tables 13 and 34. Graduate students (Postdoctoral appointees) in science, engineering, and health: 2011–16 by field, citizenship, ethnicity, and race, total. https://ncsesdata.nsf.gov/gradpostdoc/2016/

Table C-2. Total Number of Post-Doctoral Scholars in STEM Disciplines in the United States

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	1,290	21,611	760	7,103	902	9,386	41,052
2013	1,319	21,026	765	7,106	932	9,229	40,377
2014 (old)	1,395	20,527	833	7,292	956	9,148	40,151
2014 (new)	1,402	21,432	834	7,307	959	9,338	41,272
2015	1,525	21,261	888	7,656	1,011	9,487	41,828
2016	1,484	21,498	914	7,796	1,005	9,373	42,070
2017	1,024	21,781	854	7,839	991	9,300	41,789
2018	1,072	21,533	879	7,914	982	8,702	41,082
2019	1,079	21,847	878	8,266	1,070	8,937	42,077
2020	1,678	21,902	823	8,462	1,076	8,727	42,668
2021	1,595	20,245	880	8,340	1,112	8,620	40,792

Note: In 2014, NSF updated the survey frame following a comprehensive frame evaluation study that identified potentially eligible but not previously surveyed academic institutions in the United States with graduate in science, engineering, or health. A total of 151 newly eligible institutions were added, and two private for-profit institutions offering mostly practitioner-based graduate degrees were determined to be ineligible.

Source: 2017 through 2021: NSF NCSES. Survey of Graduate Students and Postdoctorates in Science and Engineering. Tables 2-2. Citizenship, ethnicity, and race of graduate students, postdoctoral appointees, and doctorate-holding nonfaculty researchers in science (engineering), by sex. Link for 2021 data: https://ncses.nsf.gov/pubs/nsf23312/table/5-3#section14012

2012 through 2016: Survey of Graduate Students and Postdoctorates in Science and Engineering Fall 2016. Tables 13 and 34. Graduate students (Postdoctoral appointees) in science, engineering, and health: 2011–16 by field, citizenship, ethnicity, and race, total. https://ncsesdata.nsf.gov/gradpostdoc/2016/

Table C-3. Percentage of STEM Post-Doctoral Scholars in the United States Who Are International

Year	Agriculture and Related Sciences	Biological and Biomedical Sciences	Computer and Information Sciences	Engineering	Mathematics and Statistics	Physical Sciences	Total
2012	44.57%	54.05%	60.92%	61.45%	49.45%	55.49%	55.39%
2013	44.12%	53.31%	60.52%	61.92%	47.64%	54.92%	54.90%
2014 (old)	48.03%	53.47%	61.58%	61.75%	54.81%	55.80%	55.52%
2014 (new)	48.00%	53.83%	61.63%	61.79%	54.85%	55.94%	55.70%
2015	50.10%	55.46%	64.08%	67.07%	61.13%	58.84%	58.48%
2016	49.12%	54.22%	64.11%	66.78%	57.11%	58.21%	57.54%
2017	58.20%	53.54%	66.51%	66.19%	55.20%	57.44%	57.20%
2018	55.22%	54.64%	61.66%	66.44%	53.67%	59.26%	58.03%
2019	59.31%	56.25%	64.35%	67.47%	55.14%	60.73%	59.63%
2020	49.28%	54.64%	62.70%	66.99%	52.32%	58.47%	57.76%
2021	50.91%	54.53%	60.23%	65.14%	49.55%	56.64%	56.99%

Note: In 2014, NSF updated the survey frame following a comprehensive frame evaluation study that identified potentially eligible but not previously surveyed academic institutions in the United States with graduates in science, engineering, or health. A total of 151 newly eligible institutions were added, and two private for-profit institutions offering mostly practitioner-based graduate degrees were determined to be ineligible.

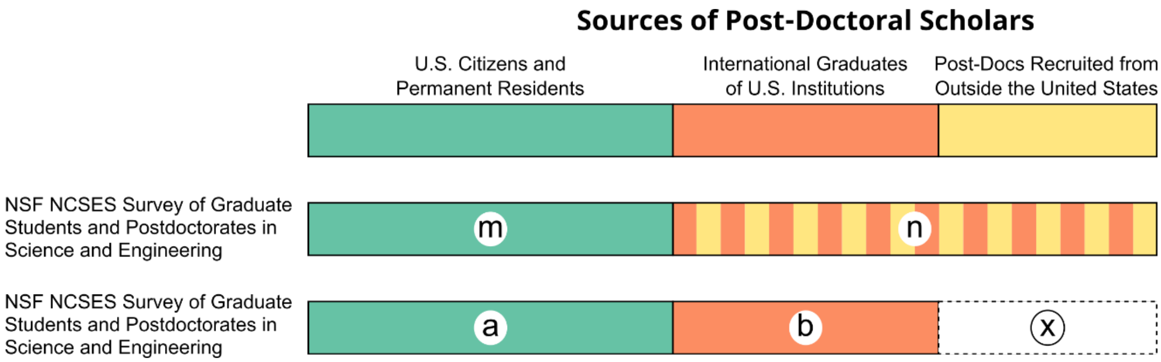
Table C-4. Annual Influx of Foreign-trained, U.S.-trained International, and U.S.-trained Domestic Post-doctoral Scholars

Year	U.S. Citizens and Permanent Residents	International Doctoral Graduates of U.S. Institutions	Post-doctoral Scholars Recruited from Outside United States
2012	4,542	2,846	2,793
2013	4,321	2,722	2,538
2014	4,319	2,594	2,836
2015	4,335	2,746	3,359
2016	4,604	2,738	3,502
2017	4,834	3,249	3,212
2018	5,013	3,367	3,565
2019	5,024	3,475	3,945
2020	4,909	3,680	3,033
2021	4,921	3,588	2,933

Note: For 2021: NSF Survey of Earned Doctorates. Table 6-2. U.S. citizen and permanent resident research doctorate recipients with definite postgraduation commitments, by major field of doctorate, and Table 6-3. Temporary visa holder research doctorate recipients with definite postgraduation commitments, by major field of doctorate. https://ncses.nsf.gov/pubs/nsf23300/data-tables

For 2012 through 2020: NSF Survey of Earned Doctorates. Table 51. Definite postgraduation commitments of doctorate recipients, by citizenship status and major field of study. https://www.nsf.gov/statistics/srvydoctorates-legacy/#tabs-2

Number of post-doctoral scholars recruited from outside United States annually was calculated in the following manner.



Known:

a = number of domestic (U.S. citizen or permanent resident) U.S.-trained doctoral students reporting intention to post-doc in United States annually

b = number of international U.S.-trained doctoral students reporting intention to post-doc in United States annually

m = standing number of domestic post-docs in United States

n = standing number of international post-docs in United States (post-docs with U.S. doctoral degree plus post-docs with foreign doctoral degree)

Unknown:

x = number of foreign-trained doctoral students coming to post-doc in United States annually

Assuming that the rate of turnover (i.e., the average duration spent as a post-doctoral scholar) is the same for all three categories of post-doc, the proportion of domestic post-docs starting annually can be set equal to the proportion of standing post-docs who are domestic:

$$\frac{a}{a+b+x} = \frac{m}{m+n} \qquad (1).$$

Rearranging equation (1) to determine number of foreign-trained doctoral students starting post-docs in the United States annually yields:

$$x = \frac{an-bm}{m} \qquad (2).$$

Appendix D.
U.S. STEM Workforce

Table D-1. U.S. STEM Workforce (thousands)

Year	Computer and mathematical occupations	Architecture and engineering occupations	Life, physical, and social science occupations	Total STEM	Total U.S. workforce
2012	3,816	2,846	1,316	7,978	142,469
2013	3,980	2,806	1,307	8,093	143,929
2014	4,303	2,798	1,355	8,456	146,305
2015	4,369	2,954	1,404	8,727	148,834
2016	4,601	3,106	1,367	9,074	151,436
2017	4,804	3,224	1,431	9,459	153,337
2018	5,126	3,263	1,529	9,918	155,761
2019	5,352	3,305	1,485	10,142	157,538
2020	5,603	3,169	1,627	10,399	147,795
2021	5,688	3,235	1,640	10,563	152,581
2022	6,171	3,464	1,840	11,475	158,291

Source: Bureau of Labor Statistics, Labor Force Statistics from the Current Population Survey (2012–2022), Household Annual Averages, Table 9. Employed persons by occupation, sex, and age. https://www.bls.gov/cps/cpsaat09.htm

Table D-2. Foreign-Born Workers Employed in STEM Occupational Categories (thousands)

Year	Percentage of foreign-born workers employed in computer and mathematical occupations	Percentage of native-born workers employed in computer and mathematical occupations	Percentage of foreign-born workers employed in architecture and engineering occupations	Percentage of native-born workers employed in architecture and engineering occupations	Percentage of foreign-born workers employed in life, physical, and social science occupations	Percentage of native-born workers employed in life, physical, and social science occupations	Employed, foreign-born STEM workers (thousands)	Employed, native-born STEM workers (thousands)	Total employed foreign-born workforce (thousands)	Total employed native-born workforce (thousands)
2012	3.8	2.5	2.2	2.0	1.0	0.9	1,610	6,451	23,006	119,464
2013	3.9	2.5	2.2	1.9	1.1	0.9	1,698	6,378	23,582	120,348
2014	4.3	2.7	2.2	1.9	1.1	0.9	1,845	6,711	24,282	122,023
2015	4.3	2.7	2.2	1.9	1.2	0.9	1,922	6,813	24,963	123,871
2016	4.6	2.7	2.2	2.0	1.2	0.8	2,062	6,911	25,779	125,657
2017	4.8	2.8	2.3	2.1	1.3	0.9	2,205	7,371	26,254	127,083
2018	5.1	2.9	2.2	2.1	1.2	0.9	2,313	7,584	27,217	128,544
2019	5.2	3.0	2.3	2.0	1.2	0.9	2,393	7,672	27,502	130,036
2020	5.8	3.4	2.4	2.1	1.3	1.1	2,357	8,117	24,809	122,986
2021	5.7	3.3	2.5	2.0	1.3	1.0	2,511	7,947	26,431	126,150
2022	5.7	3.5	2.4	2.1	1.6	1.1	2,787	8,680	28,737	129,554

Sources: Bureau of Labor Statistics, Foreign-Born Workers: Labor Force Characteristics, Table 4.

2022: USDL-23-1013. https://www.bls.gov/news.release/pdf/forbrn.pdf

2021: USDL-22-0902. https://stats.bls.gov/news.release/archives/forbrn_05182022.pdf

2020: USDL-21-0905. https://www.bls.gov/news.release/archives/forbrn_05182021.pdf

2019: USDL-20-0922. https://www.bls.gov/news.release/archives/forbrn_05152020.pdf

2018: USDL-19-0812. https://www.bls.gov/news.release/archives/forbrn_05162019.pdf

2017: USDL-18-0786. https://www.bls.gov/news.release/archives/forbrn_05172018.pdf

2016: USDL-17-0618. https://www.bls.gov/news.release/archives/forbrn_05182017.pdf

2015: USDL-16-0989. https://www.bls.gov/news.release/archives/forbrn_05212015.pdf

2014: USDL-15-0971. https://www.bls.gov/news.release/archives/forbrn_05212015.pdf

2013: USDL-14-0873. https://www.bls.gov/news.release/archives/forbrn_05222014.pdf

2012: USDL-13-0991. https://www.bls.gov/news.release/archives/forbrn_05222013.pdf

Table D-3. Number of New H-1B Visa Approvals

Year	Total	STEM	Computer-Related Occupations	Universities and Colleges
2012	136,890	101,496	83,444	8,515
2013	128,291	96,435	79,870	7,635
2014	124,326	96,037	80,877	7,274
2015	113,603	85,637	70,902	7,224
2016	105,090	84,408	69,846	8,185
2017	96,167	82,422	66,848	7,324
2018	87,894	66,410	48,017	7,430
2019	132,986	104,902	78,003	8,555
2020	122,886	93,800	72,391	10,016
2021	123,414	94,675	75,372	9,363
2022	132,429	111,585	74,668	11,224

Sources: USCIS Characteristics of H-1B Specialty Occupation Workers (2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022)

Table D-4. New H-1B Visas Approvals by STEM Occupational Category

Year	Computer-Related Occupations	Architecture, Engineering, Surveying	Mathematics and Physical Sciences	Life Sciences	All H-1B Approvals
2012	83,444	13,082	2,465	2,505	136,890
2013	79,870	11,642	2,405	2,518	128,291
2014	80,877	10,707	2,295	2,158	124,326
2015	70,902	10,003	2,441	2,291	113,603
2016	69,846	10,243	2,786	1,533	105,090
2017	66,848	10,510	2,750	2,314	96,167
2018	48,017	11,952	4,079	2,362	87,894
2019	78,003	17,791	5,855	3,253	132,986
2020	72,391	13,525	4,663	3,221	122,886
2021	75,372	11,785	4,358	3,160	123,414
2022	74,668	30,224	2,700	3,993	132,429

Sources: USCIS Characteristics of H-1B Specialty Occupation Workers, Table 7. H-1B Petitions Approved by Major Occupation Group and Type of Petition.

2022: https://www.uscis.gov/sites/default/files/document/data/OLA_Signed_H-1B_Characteristics_Congressional_Report_FY2022.pdf

2021: https://www.uscis.gov/sites/default/files/document/data/H1B_Characteristics_Congressional_Report_FY2021-3.2.22.pdf

2020: https://www.uscis.gov/sites/default/files/document/reports/Characteristics_of_Specialty_Occupation_Workers_H-1B_Fiscal_Year_2020.pdf

2019: https://www.uscis.gov/sites/default/files/document/reports/Characteristics_of_Specialty_Occupation_Workers_H-1B_Fiscal_Year_2019.pdf

2018: https://www.uscis.gov/sites/default/files/document/reports/Characteristics_of_Specialty_Occupation_Workers_H-1B_Fiscal_Year_2018.pdf

2017: https://www.uscis.gov/sites/default/files/document/reports/Characteristics-of-Specialty-Occupation-Workers-H-1B-Fiscal-Year-2017.pdf

2016: https://www.uscis.gov/sites/default/files/document/reports/h-1B-FY16.pdf

2015: https://www.uscis.gov/sites/default/files/document/data/H-1B-FY15.pdf

2014: https://www.uscis.gov/sites/default/files/document/reports/h-1B-characteristics-report-14.pdf

2013: https://www.uscis.gov/sites/default/files/document/reports/H-1B_Characteristics_Report_FY_2013_826_KB.pdf

2012: https://www.uscis.gov/sites/default/files/document/reports/h1b-fy-12-characteristics.pdf

Table D-5. Number of Permanent Residency Approvals 2012–2022

Year	All Employment-Based Approvals	EB-1, EB-2, and EB-3 Approvals	All Family-Sponsored Approvals
2012	143,998	129,504	202,019
2013	161,110	145,636	210,303
2014	151,596	132,511	229,104
2015	144,047	123,275	213,910
2016	137,893	117,653	238,087
2017	137,855	118,474	232,238
2018	138,171	118,837	216,563
2019	139,458	120,764	204,139
2020	148,959	134,272	121,560
2021	193,338	175,384	65,690
2022	270,284	241,876	166,041

Sources: DHS Office of Immigration Statistics, Yearbook of Immigration Statistics 2022, Table 6. Persons Obtaining Lawful Permanent Resident Status by Type and Major Class of Admission: Fiscal Years 2013 to 2022. https://www.dhs.gov/immigration-statistics/yearbook/2022

DHS Office of Immigration Statistics, Yearbook of Immigration Statistics 2021, Table 6. Persons Obtaining Lawful Permanent Resident Status by Type and Major Class of Admission: Fiscal Years 2012 to 2021. https://www.dhs.gov/immigration-statistics/yearbook/2021

Table D-6. STEM Labor Certification Approvals 2012–2022

Year	Total Certifications for Employment-Based Permanent Residency	Permanent Residency Certifications for Computer-Related Occupations	Permanent Residency Certifications for Mathematical Science Occupations	Permanent Residency Certifications for Engineering Occupations	Permanent Residency Certifications for Physical Science Occupations	Permanent Residency Certifications for Life Science Occupations
2015	34,571	18,704	596	3,860	181	215
2016	50,156	28,228	892	4,662	277	250
2017	35,585	19,873	688	3,144	238	168
2018	61,299	31,282	1,714	5,840	357	248
2019	45,784	23,514	1,448	4,638	210	190
2020	44,733	22,970	1,527	4,183	226	154
2021	57,000	28,898	2,168	5,062	405	208
2022	32,800	16,545	1,486	3,024	185	118

Sources: Numbers extracted from DOL labor certification disclosure data for employment-based permanent residency applications. https://www.dol.gov/agencies/eta/foreign-labor/performance

Table D-7. Annual Unemployment Levels (Percentage) for STEM Occupations

Year	Computer and mathematical occupations	Architecture and engineering occupations	Life, physical, and social science occupations	Total STEM	Total U.S. workforce
2012	3.6	4.2	4.0	3.9	8.1
2013	3.6	3.5	3.6	3.6	7.4
2014	2.7	3.1	3.8	3.0	6.2
2015	2.6	2.6	2.8	2.6	5.3
2016	2.5	2.5	2.4	2.5	4.9
2017	2.4	2.4	2.4	2.4	4.4
2018	2.1	1.8	2.0	2.0	3.9
2019	2.0	1.7	1.8	1.9	3.7
2020	3.4	3.6	4.3	3.6	8.1
2021	2.1	2.6	3.0	2.4	5.3
2022	1.9	1.5	1.4	1.7	3.6

Source: BLS Current Population Survey, Household Data Annual Averages, Table 25. Unemployed Persons by Occupation and Sex.

2022: https://www.bls.gov/cps/cpsaat25.htm

2012–2021: Table 25 at https://www.bls.gov/cps/tables.htm#otheryears

Table D-8. Median Weekly Wages for STEM Occupations (2022 $) 2012–2022

Year	Computer and mathematical occupations	Architecture and engineering occupations	Life, physical, and social science occupations	Total U.S. Workforce
2012	$1,102.03	$1,092.23	$926.39	$627.40
2013	$1,130.94	$1,130.94	$954.46	$642.94
2014	$1,151.53	$1,159.11	$983.18	$665.83
2015	$1,208.45	$1,205.07	$1,020.58	$684.62
2016	$1,228.81	$1,262.02	$1,029.54	$708.50
2017	$1,268.61	$1,279.86	$1,113.60	$744.71
2018	$1,363.11	$1,314.40	$1,124.85	$784.74
2019	$1,423.43	$1,397.29	$1,202.57	$826.66
2020	$1,500.00	$1,446.72	$1,227.19	$903.86
2021	$1,567.92	$1,549.97	$1,328.95	$942.64
2022	$1,789.00	$1,735.00	$1,463.00	$1,059.00

Source: BLS Current Population Survey, Household Data Annual Averages, Table 39. Median Weekly Earnings of Full-Time Wage and Salary workers by Detailed Occupation and Sex.

2022: https://www.bls.gov/cps/cpsaat39.htm

2012–2021: Table 29 at https://www.bls.gov/cps/tables.htm#otheryears

Conversion to 2022 dollars: The White House, Historical Tables. Table 10.1—Gross Domestic Product and Deflators Used in the Historical Tables: 1940–2028. https://www.whitehouse.gov/wp-content/uploads/2023/03/hist10z1_fy2024.xlsx

Appendix E.
U.S. STEM Talent Overseas

Table E-1. Reported Number of U.S.-born Foreign Residents in OECD Countries

Year	Total Reported	High-Skilled Workers (Tertiary Education)	High-Skilled Professionals	High-Skilled Science and Engineering or Information and Communications Professionals
2000/2001	840,561	391,408	106,554	15,425
2005/2006	725,924	346,659	84,941	8,414
2010/2011	1,812,190	555,622	163,923	8,486
2015/2016	1,977,121	653,584	221,117	15,425

Sources: Numbers extracted from OECD Social, Employment and Migration Working Papers 114, 126, 160, and 239. Data source: https://www.oecd.org/els/mig/dioc.htm

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Abbreviations

BLS	Bureau of Labor Statistics
DHS	Department of Homeland Security
DOL	Department of Labor
DOS	Department of State
EB	employment-based
HEFERP	High-End Foreign Expert Recruitment Program
IDA	Institute for Defense Analyses
IPEDS	Integrated Postsecondary Education Data System
ISTC	Subcommittee on International Science and Technology Coordination
LCA	labor condition application
LPR	lawful permanent resident
NCSES	National Center for Science and Engineering Statistics
NSB	National Science Board
NSF	National Science Foundation
NSTC	National Science and Technology Council
OECD	Organisation for Economic Co-operation and Development
OEWS	Occupational Employment and Wage Statistics
OPT	optional practical training
OSTP	Office of Science and Technology Policy
PCAST	President's Council of Advisors on Science and Technology
SDR	Survey of Doctoral Recipients
SED	Survey of Earned Doctorates
STEM	science, technology, engineering, and math
STPI	Science and Technology Policy Institute
USCIS	U.S. Citizenship and Immigration Services

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14. ABSTRACT
The White House Office of Science and Technology Policy asked the Science and Technology Policy Institute to support the National Science and Technology Council (NSTC) Subcommittee on International Science and Technology Coordination (ISTC) to synthesize existing reports and data sources to address the following recommendation from the 2022 NSTC ISTC Report to Congress: Conduct research to understand why STEM [science, technology, engineering, and math] talent leaves the United States or chooses to go to other countries, including examining the entire innovation pipeline to identify research, development, regulatory, statutory, capacity, and infrastructure challenges to STEM talent recruitment and retention. The report uses publicly available information to estimate the magnitude of talent flows in and out of the U.S. STEM ecosystem and reviews the current literature on the reasons that STEM talent comes to, stays, and leaves the United States. In addition, it develops a conceptual model for understanding the movement of talent through the U.S. STEM ecosystem with the aim of identifying gaps to be addressed in future research and data collection.

15. SUBJECT TERMS
science, technology, engineering, and math (STEM); International Science and Technology Coordination (ISTC); international students; foreign temporary workers; STEM education; STEM workforce; STEM ecosystem

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