Reimagining STEM Graduate Education: A Landscape View of a System in Transition

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July 2025

This paper was commissioned for the “Reimagining STEMM Graduate Education and Postdoctoral Career Development” Summit. Opinions and statements included in the paper are solely those of the individual authors, and are not necessarily adopted, endorsed, or verified as accurate by the Summit planning committee or the National Academies of Sciences, Engineering, and Medicine.

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Introduction

Breakthroughs that define the twenty-first century, from the first detection of gravitational waves to the advent of CRISPR genome editing, trace their origins to America's graduate laboratories and classrooms. Yet the playbook that produced yesterday's successes is under strain. New forms of data-intensive and interdisciplinary research, heightened expectations for ethical engagement with society, and a changing labor market are reshaping what future scientists must know and do.[1]

Recognizing this inflection point, the National Academies of Sciences, Engineering, and Medicine commissioned this paper to provide a high-level ecosystem view focused on the graduate students whose learning, labor, and well-being connect discovery to public benefit.[2]

The report proceeds in five parts. It maps the structural actors and incentives that shape U.S. graduate education; describes the multifaceted roles trainees already play in research, teaching, and civic life; synthesizes a decade of reform calls; highlights emerging solutions across sectors; and analyzes recent federal policy shifts.

A central theme animating this report is not whether reform is necessary, but how existing momentum can be harnessed to build a graduate education system that simultaneously advances science, serves society, and supports every trainee equitably.

Major Structural Elements and Pressures in U.S. STEM Graduate Education Ecosystem

Principal Investigators (Faculty Advisors)

Principal investigators (PI), typically tenure-stream faculty, occupy the most immediate and consequential position in a trainee's professional life. Their laboratories supply the funding, intellectual direction, and day-to-day environment in which graduate students and postdoctoral researchers conduct research. Powered by both structural incentives and personal drivers, PIs face intense pressure to win grant funding (the essential currency for sustaining a lab and meeting tenure or promotion metrics), publish in high-impact venues that evaluators and funders track, and build a high-performing team whose accomplishments amplify the PI's reputation. Concurrently, many investigators are propelled by personal motivations such as intellectual curiosity, commitment to discovery, and a desire to foster the growth of their trainees. They

[1] This paper focuses on Science, Technology, Engineering, and Mathematics (STEM) rather than Science, Technology, Engineering, Mathematics, and Medicine (STEMM). While medicine is deeply interconnected with science and engineering, graduate medical education has different and distinct goals, structures, and systems that are not addressed in this commissioned paper.

[2] The author would like to thank Josh McCubbin at Idaho State University for his research assistance in support of this paper.

exert influence primarily by shaping trainees' career outcomes. As chair (or dominant voice) of a student's dissertation committee, the PI ultimately determines when a body of work is "sufficient" for the degree and thus controls both whether and when a student earns a PhD. PIs also dictate authorship order, craft recommendation letters, and broker introductions to important collaborators and prospective employers, decisions that resonate throughout a trainee's career. This power a PI holds over the student's career has the potential to be problematic and can leave students feeling exploited for their labor (Friedensen et al., 2024; NASEM, 2018a). On the other hand, high-quality mentorship remains strongly correlated with well-being as students with supportive mentors have higher rates of retention and less anxiety and depression (Evans et al., 2018). Finally, through their daily behavior, PIs model laboratory norms on work hours, inclusivity, research ethics, and responses to error. Because prevailing reward systems still privilege research output over mentoring, many investigators prioritize productivity unless universities and funders explicitly recognize and reward effective advising.

Universities and Academic Institutions

Universities are not a single institutional stakeholder, but rather are composed of a number of internal leaders (e.g., department chairs, deans, provosts, and boards of trustees) who make decisions that determine how STEM graduate education is financed, organized, and judged. While each individual in the system may have personal motivations for their work, they have a shared interest in attracting the best talent and necessary revenue to advance the university's mission. Keeping laboratories active and students funded requires a steady flow of dollars. Federal grants, as of 2023, still supply more than half of university R&D spending, and the indirect cost recovery on these awards underwrites lab renovations, facilities, and university administration (NCSES, 2024). Additional revenue streams include professional master's degrees and undergraduate tuition, industry research collaborations, alumni giving, and philanthropic gifts. Simultaneously, rankings, citation counts, and placement metrics shape competition for students, faculty, and donors. Demonstrable research success and reputation push an institution up college ranking tables and, in turn, attract even more resources (Selten et al., 2020).

Under these twin incentives, university leaders set the financial and cultural parameters of graduate study. They determine admissions targets, allocate assistantships, assign lab space, hire faculty, and approve degree requirements and timelines. They also enforce compliance with federal and state regulations that condition continued funding. These decisions influence the graduate experience in substantial ways. Because revenue targets funnel resources toward grant-rich disciplines, students in well-funded fields are more likely to have stable stipends, up-to-date instrumentation, and ample conference travel, whereas peers in less lucrative areas often face thinner support packages and heavier teaching loads. Moreover, students at well-resourced institutions often benefit from greater baseline support, even in less grant-rich disciplines, than their peers in better-funded fields at less wealthy institutions, highlighting how institutional wealth can mitigate or exacerbate disparities in graduate training environments. Reputation-driven benchmarks for rapid completion translate into compressed milestone calendars and intensified publication pressure. At best, these forces provide a structured, resource-rich environment that accelerates skill development and expands career-readiness programming; at worst, they heighten financial insecurity, sharpen competition, and exacerbate stress and mental-health risks.

Professional Societies and Nonprofit Organizations

Professional societies and nonprofit organizations play a vital, though often indirect, role in shaping the landscape of graduate STEM education. These include discipline-specific societies like the American Physical Society (APS), the American Chemical Society (ACS), and cross-cutting organizations such as the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS). They play a major role in maintaining disciplinary standards and informing accrediting bodies, while also serving broad membership bases (Leibnitz et al., 2022).

These organizations exert influence through programming, advocacy, and norm-setting. They organize annual meetings that serve as critical networking hubs for early-career scientists, fund travel awards, and run leadership development workshops for students. Some sponsor research and teaching awards, produce ethics guidelines, or publish position papers that influence institutional policies (Meyer-Gutbrod et al., 2023). APS, for instance, established the Bridge Program to improve the representation of underrepresented minorities in physics graduate programs, providing mentoring structures and institutional support that “has enabled over 100 students to be placed into Bridge or graduate programs in physics, while retaining 88% of those placed” (Beckford, 2017).

For graduate students, participation in societies can build professional identity, provide mentorship and training opportunities beyond one’s institution, and facilitate job placement through career fairs and job boards. These groups often fill gaps that universities leave unaddressed, such as culturally responsive mentoring, community building for marginalized groups, or training in science policy and communication. However, access to these benefits may depend on factors that are unevenly distributed across institutions: awareness of such opportunities, advisor encouragement, and availability of travel funds,.

Academic Journals

Academic journals occupy a powerful position in the research ecosystem by determining what gets published, when, and with what level of prestige. The dominant motivations of high-impact journals center on maintaining reputational authority, maximizing citations and readership, and, in some cases, driving subscription revenue or author-side fees. Journals indirectly influence graduate training by shaping what counts as a publishable unit of work, what kinds of findings are considered novel, and which methodologies and author demographics are represented or excluded.

Journals exert influence by acting as gatekeepers to scientific legitimacy. Peer review processes, editorial decisions, and impact factor rankings collectively determine the visibility and valuation of a student's work. In academic departments and institutions where first-author publications are required for graduation or fellowships, delays or rejections can extend time-to-degree or derail funding eligibility. Moreover, journal expectations can implicitly shape advising practices, lab timelines, and even topic selection, especially when prestigious journals favor certain paradigms or institutions.

For graduate students, journals help define what success looks like. A paper in a prestigious venue can unlock fellowships, postdocs, or academic job offers. Conversely, bias against particular research approaches, such as qualitative studies, the use of indigenous knowledge, or incorporating community participation, may disadvantage certain students, especially those from marginalized backgrounds. The emergence of preprint servers and open-access publishing has begun to shift this landscape, but the cultural capital of top journals remains potent.

Industry and Private-Sector Employers

Private-sector employers, including biotechnology firms, engineering consultancies, and information technology companies, are key stakeholders in the graduate education ecosystem by virtue of employing a substantial share of STEM PhD graduates (NCSES, 2021). Their motivations are largely market-driven: securing specialized talent, advancing product development, and maintaining competitive advantage in a knowledge economy. These employers are increasingly vocal in articulating the skills and experiences they seek, which in turn shapes how graduate programs design curricula and experiential learning.

Industry exerts influence on the graduate experience both directly and indirectly. Directly, firms offer internships, research sponsorships, and job placements that give graduate students exposure to applied settings. Indirectly, they participate in advisory boards, influence research priorities (especially in public-private partnerships), and shape public discourse around innovation needs. Some firms collaborate with universities to co-design professional science master's programs or data science bootcamps tailored to employer demands.

For graduate students, industry's presence opens diverse career pathways and provides financial incentives for skills acquisition. Exposure to private-sector research can accelerate job readiness, inform dissertation focus, and alleviate financial pressures through internships or external funding. However, disparities in access to these opportunities by discipline, geographic region, university reputation, or advisor support can reinforce existing inequities. Furthermore, an overemphasis on industry alignment may inadvertently narrow intellectual exploration or undervalue basic research.

Private Philanthropy

Philanthropic foundations, such as the Howard Hughes Medical Institute, the Simons Foundation, and the Alfred P. Sloan Foundation, have become increasingly influential in shaping scientific research. As of 2019, private grants provide support that "rivals the funding offered by the top national science funders in the US, with the combined total exceeding the yearly amount awarded by NSF and being comparable to the amount distributed yearly by the NIH" (Shekhtman et al., 2024). These organizations are motivated by a desire to accelerate scientific discovery, promote inclusive excellence, and experiment with educational models that may be difficult to implement through traditional federal funding mechanisms. Many also view graduate education as a leverage point for long-term societal change, whether through diversifying the research workforce or fostering interdisciplinary solutions to complex global problems.

Philanthropy exerts its influence by funding graduate fellowships, seeding new training programs, underwriting curriculum reforms, and supporting centers for inclusive pedagogy and mentorship. Because philanthropic grants often come with fewer bureaucratic constraints than public funding, they allow for more rapid experimentation and can drive institutional innovation. Foundations also shape discourse around graduate education priorities by sponsoring national convenings, releasing white papers, and aligning their funding strategies with specific policy goals.

For graduate students, philanthropic investment can open new opportunities for financial support, professional development, and interdisciplinary training. Fellowship programs often provide generous stipends, research allowances, and networking opportunities that buffer students from institutional funding gaps and enhance career readiness. However, access to these benefits is not equally distributed: prestigious philanthropic awards tend to concentrate in elite institutions and may reinforce inequities in opportunity across the academic landscape. Additionally, the time-limited nature of foundation initiatives means that students in later cohorts may not experience the same benefits if programs are not institutionalized.

The Public (via State and Federal Government)

Public funding, appropriated by legislatures and disbursed through executive agencies such as the National Science Foundation (NSF), National Institutes of Health (NIH), Department of Energy (DOE), and National Aeronautics and Space Administration (NASA), constitutes the financial backbone of the U.S. research and graduate education ecosystem. While policymakers, agencies, and university systems act as intermediaries, the ultimate stakeholder is the American public, whose tax dollars sustain the infrastructure, personnel, and discovery efforts that characterize STEM training. The public interest is reflected in government efforts to bolster national innovation capacity, advance solutions to urgent societal challenges such as disease and climate change, and cultivate a highly skilled and diverse workforce.

The public, through its elected representatives and appointed agency leaders, exerts influence by setting funding levels, defining research priorities, and establishing rules and incentives that shape graduate education. Federal agencies provide the majority of academic R&D dollars (NCSES, 2024) and administer competitive training grants and fellowships that embed specific curricular, mentoring, and reporting requirements. State governments determine operating budgets for public universities, set tuition policy, and legislate public-sector labor rights, which increasingly govern graduate worker unionization efforts.

For graduate students, these levers of public accountability translate into tangible impacts. Differences in state appropriations contribute to wide variability in stipend levels, tuition waivers, and the quality of lab infrastructure across institutions. Federal priorities, dependent on presidential administrations, help dictate the topics students pursue, steering research toward fields like quantum computing, artificial intelligence, pandemic preparedness, or climate resilience. Requirements tied to federal training grants increasingly include evidence-based mentoring plans and, prior to 2025, diversity, equity, and inclusion (DEI) metrics, which can improve aspects of the student experience. Yet these same structures can present constraints: stagnant or reduced federal budgets and restrictive immigration policies may limit research opportunities, extend time-to-degree, or create uncertainty for international students who comprise a significant portion of the graduate STEM workforce.

Long-Standing Federal Graduate Student Assistance Programs	
Program	History
NSF Graduate Research Fellowship Program (GRFP)	Started in 1952, the GRFP supports graduate students in STEM fields. As of June 2025, it has been awarded to 1,500 students (down from 2,000 in 2024), providing a $37,000 annual stipend and $16,000 for tuition for up to three years. Over 75,000 students have received the fellowship since its founding.
Graduate Assistance in Areas of National Need (GAANN)	Established in 1988 through the Higher Education Act, GAANN provides grants to universities to support financially needy graduate students in high-priority fields like engineering and education. Institutions distribute stipends and cover educational costs, focusing on underrepresented students and national workforce needs.
National Defense Science and Engineering Graduate (NDSEG) Fellowship	Created by Congress in 1989, NDSEG is funded by the U.S. Army, Navy, and Air Force to support doctoral students in defense-relevant STEM fields. It covers full tuition, a ~$40,800 annual stipend, and other allowances for three years. No military service is required.

DOE Computational Science Graduate Fellowship (CSGF)	Launched in 1991, CSGF supports PhD students using high-performance computing for complex science and engineering problems. Fellows receive full tuition, a ~$45,000 stipend, a professional development allowance, and a practicum at a DOE national lab.
NASA Space Grant and Graduate Fellowships	Started in 1989, the Space Grant program funds fellowships, scholarships, and outreach through a network of institutions in every state, the District of Columbia, and Puerto Rico. It aims to expand participation in NASA-related STEM fields through education and research support.
NSF Research Traineeship (NRT) Program	Established in 2014, NRT funds innovative graduate training at universities rather than individual fellowships. It emphasizes interdisciplinary research and career readiness, awarding grants (typically $2–3 million) to develop new education models aligned with workforce needs.
NIH Institutional National Research Service Award (T32)	Launched in 1974, NIH T32 institutional training grants support universities, not individual trainees, to build structured, cohort-based programs in priority research areas. Awards (usually around $1–1.5 million over five years) fund stipends, tuition, and enhanced professional-development activities, requiring robust mentoring plans and diversity efforts that prepare pre- and postdoctoral scholars for biomedical and behavioral science careers.

The Current Roles of STEM Graduate Students in the U.S. Research Ecosystem

Graduate students in STEM arrive at their programs expecting a rigorous education in science and engineering. What many soon realize, however, is that they are not just students; they are essential contributors to the university's research and teaching missions. Their two official responsibilities, conducting research and teaching undergraduates, are foundational to the functioning of U.S. higher education and scientific discovery. In addition to these formal duties, graduate students often take on numerous additional roles that, while typically unofficial and underrecognized, are vital to the research ecosystem. These include lab and departmental service, public engagement, interdisciplinary collaboration, diversity and inclusion advocacy, and labor organizing.

Core Research Workforce

Graduate students are not just learning science; they are the science workforce. Federal data indicate that 69% of federally funded, full-time science and engineering graduate students are supported as research assistants (NCSES, 2023a). As highlighted by the National Academies of Sciences, Engineering, and Medicine, "Graduate students and postdoctoral researchers… conduct a large percentage of the day-to-day research work at universities"(NASEM, 2018a). Together, these data show that STEM graduate students form a fundamental part of the U.S. research labor force, leading experiments and studies at the forefront of discovery.

Graduate researchers are instrumental in generating data, resolving complex equipment issues, developing software, and analyzing results that underpin new knowledge. Their responsibilities extend to scholarly dissemination. For example, an analysis of predoctoral fellowship recipients found that 73–75% of these graduate trainees published at least one first-author paper during their fellowship period (Schaller, 2021). In short, graduate students not only perform the bulk of experimental work but also translate those findings into the publications and presentations that drive scientific progress.

Undergraduate Teaching, Mentoring & Curricular Support

Beyond their primary research contributions, STEM graduate students play a pivotal role in the academic development of undergraduate students. They are frequently employed as Graduate Teaching Assistants (GTAs), undertaking diverse teaching responsibilities that include grading assignments, leading discussion or recitation sessions, and instructing laboratory classes for introductory undergraduate courses. The prevalence of GTAs in undergraduate education is substantial; for instance, a 2005 survey found that 91% of undergraduate biology laboratory sections in U.S. research institutes were taught by GTAs (Sundberg et al., 2005). Similarly, a national survey found that GTAs are responsible for nearly 30% of introductory statistics courses offered in mathematics departments (Blair et al., 2013).

Graduate students are not merely teaching assistants but crucial pedagogical agents influencing undergraduate academic pathways and retention in STEM. Research indicates that “undergraduates who take their first course in a given subject from a graduate student are nearly twice as likely to subsequently major in that subject compared to their peers who take the same course from full-time faculty” (Bettinger et al., 2016). This highlights their often-underestimated role in shaping the future STEM workforce at foundational levels, demonstrating their capacity to inspire and guide students into STEM disciplines.

Unrecognized but Essential Roles

In addition to their core responsibilities, graduate students often shoulder substantial unofficial labor. This includes managing lab operations, organizing seminars and outreach events, serving on departmental committees, and mentoring peers. Such tasks are critical to the daily functioning and community-building of academic units.

Moreover, students from historically marginalized groups disproportionately take on diversity, equity, and inclusion (DEI) work, mentoring younger students, leading affinity groups, and advocating for structural change (Pérez et al., 2022). While transformative, this additional service can slow academic progress and negatively affect well-being.

Graduate students also frequently assume boundary-spanning roles, communicating research to the public, collaborating across disciplines, and engaging in policy and advocacy efforts (Bennett et al., 2022). Yet these contributions typically lack formal training opportunities or recognition in graduate curricula (Muindi & Luray, 2023).

Finally, graduate students are increasingly organizing collectively to address systemic issues in academia. From 2012 through 2024, the share of unionized graduate-student employees grew by roughly 133% (Flannery, 2024). Recent contracts, such as the 2022 agreement between the University of California and UAW-represented graduate workers, secured wage increases of 40–55 % alongside expanded benefits (Jaschik, 2022; UAW 2865, n.d).

Calls for STEM Graduate Education Reform

Calls for modernizing STEM graduate education come in response to a multifaceted array of evolving challenges and opportunities that demand a fundamental reorientation of traditional approaches. The consensus across more than 20 reports and studies underscores that continuing with the status quo is no longer tenable for ensuring the nation’s competitiveness, fostering innovation, or adequately preparing a diverse workforce for the 21st century (Leshner & Scherer, 2019).

The reasons driving calls for modernization and specific reform recommendations are wide-ranging and include:

Fostering Public Engagement

A significant and urgent call for reform centers on the need to move beyond purely technical training and equip graduate students with the skills to engage with the societal and ethical dimensions of their work. There is growing consensus that in an era of complex challenges, scientists' expertise and skills are more important than ever in the public sphere. This is a perspective that, while newly prominent in national reform efforts, has long been embraced by many scientists committed to public engagement and socially responsive research.

The National Academies argue that every STEM PhD should learn to weigh ethical implications, grapple with differing viewpoints, and communicate results to non-scientific audiences (NASEM, 2018a). Similarly, the American Academy of Arts & Sciences recommends that every STEM PhD be trained in science communication and public engagement, with support from universities and scientific societies to embed these skills into curricula, research culture, and career advancement (American Academy of Arts & Sciences, 2020). At the same time, there is evidence that STEM graduate students increasingly recognize the importance of engaging with broader audiences and want training to prepare them for public engagement embedded in their core education (Schafer, 2024). Public opinion data adds urgency to these reforms with over 70 % of U.S. voters believing scientists have a duty to inform elected officials about their work, and eight in ten adults expecting researchers to explain their work to the public (Research!America, 2020a; Research!America, 2020b).

These interrelated goals are increasingly being framed under the umbrella of civic science, which encourages preparing scientists to be active citizens who engage with the societal implications of research (Christopherson, Scheufele, & Smith, 2018). Rather than introducing an entirely new agenda, civic science weaves together longstanding priorities, such as science communication, public engagement, ethics, and policy literacy, into a coherent framework that emphasizes the scientist's role as an active civic participant. A recent cross-sector working group of nationally prominent science-policy, academic, and philanthropic leaders has called for making public engagement and civic science training a required element of every STEM graduate program (Research!America, 2024). Furthermore, reformers call on federal and philanthropic funders to drive this change by phasing in this training as a requirement for federal training grants, providing clear guidelines for its inclusion in proposals, and funding new programs modeled on existing initiatives to develop and test innovative curricula that can be adopted broadly.

Training for Modern Research Skills and Diverse Career Pathways

There is growing recognition that the traditional U.S. PhD model, while still highly respected, has fallen behind evolving scientific practice and student needs (Leshner & Scherer, 2019). Most programs remain rooted in deeply specialized research projects and academic coursework. Yet modern STEM research is increasingly interdisciplinary, collaborative, and data-intensive, requiring new technical competencies in areas like coding, AI, and data science.

Employers and scientists early in their careers emphasize that PhD graduates need additional skills, such as public speaking, writing, teaching, teamwork, and leadership, to succeed in today's workplace. Reports urge programs to update graduate training by integrating both emerging technical skills and essential "soft" skills, such as communication, collaboration, and project management, into their core requirements, while also streamlining degree milestones like qualifying exams and dissertation formats to improve completion rates (NASEM, 2018a).

These changes are increasingly urgent: for over a decade now, the majority of STEM PhDs have pursued careers outside academia, and by 2023, nearly three-quarters did so (Alonso, 2025). However, graduate programs frequently neglect training for these paths, often signaling that non-academic careers are less valued within their cultures (Sherman & Hegarty, 2024). This stance can limit trainee success and broader societal impact. Experts therefore recommend embracing a "branching career pipeline" and adopting career-focused curricula, as well as offering professional development and internship opportunities, to better prepare PhD students for diverse roles in academia, industry, government, and beyond (Fuhrmann et al., 2011).

Addressing Persistent Inequities and Fostering Diversity

STEM graduate education has long struggled with the underrepresentation of women, people with disabilities, and individuals from historically marginalized racial and ethnic groups, including Black, Latinx, and Indigenous communities (NCSES, 2023b). There has been heightened awareness that structural aspects of graduate programs, from admissions criteria to departmental culture, can unwittingly perpetuate bias and exclusion. For example, heavy reliance on GRE scores in admissions was found to disadvantage many applicants from underrepresented or non-traditional backgrounds, without being predictive of success (Moneta-Koehler et al., 2017; Miller & Stassun, 2014).

Beyond admissions, reports on racial and gender climate documented that harassment, bias, and feelings of isolation are prevalent in academic departments (NASEM, 2018b). Such conditions not only harm individuals but also drive talented students out of STEM.

Calls for reform, therefore, include strong appeals to make graduate education more inclusive and equitable. This means actively fostering a welcoming, respectful culture; offering resources and networks for underrepresented students (e.g., peer support groups, minority trainee conferences); providing training on implicit bias to faculty and students; and enforcing zero-tolerance policies for discrimination and harassment.

Creating Supportive Training Environments: Mentorship, Well-Being, and Work Conditions

Efforts to improve mentorship, student well-being, and working conditions are deeply interrelated. The quality of advising and the structure of the research environment directly shape students' mental health, sense of safety, and overall graduate experience. Numerous surveys have revealed troubling levels of stress, burnout, and mental health challenges among STEM graduate students (Levecque et al., 2017). For example, in an international survey of more than 6,300 graduate students, over 40% reported working more than 50 hours per week, and nearly half cited work–life balance as one of their top challenges (Woolston, 2019). In addition, significant power imbalances in advisor-advisee relationships can result in negative impacts on student mental health, academic timelines, and financial stability.

The apprenticeship model of "sink or swim" training, with an all-consuming focus on research, is seen as no longer acceptable. Reform advocates argue that graduate programs must take a holistic approach to creating more supportive environments, implementing evidence-based mentoring practices, paying greater attention to work-life balance, and expanding access to mental health resources, all of which are necessary to promote both student well-being and academic success (NASEM, 2018a).

Rethinking Structural Incentives

The structural incentives that shape U.S. graduate education, how labs are funded, how faculty are promoted, and how success is measured, underpin many of the challenges outlined above. Reform proposals, therefore, focus on realigning incentives so that student development is rewarded alongside scientific productivity. Recommendations include shifting more trainee support from individual-investigator grants to competitive fellowships or training grants, giving students greater independence, and tying funding to evidence of mentoring quality (NASEM, 2018a). Some have called for the creation of staff scientist positions or other permanent research roles so that routine laboratory work does not rely on an ever-expanding trainee workforce (Alberts et al., 2014). On the institutional side, promotion and tenure criteria could explicitly incorporate metrics such as graduate completion rates, career outcome transparency, mentorship-training participation, and contributions to diversity, equity, and inclusion. Finally, greater transparency, publicly reporting departmental data on PhD admissions, time-to-degree, funding, and alumni careers, would allow prospective students and funders to hold programs accountable for outcomes rather than inputs, creating market pressure for sustainable lab sizes and supportive training environments.

Emerging Solutions

Numerous policy reforms and initiatives have been introduced to address key challenges in STEM graduate education. These efforts span federal and state policies, university-led reforms, labor movements, foundation and professional society programs, and the rise of the civic science movement. This section highlights a selection of efforts that have surfaced or grown over the past decade. It is not intended to be comprehensive. Rather, the aim is to illustrate the diversity of approaches being tested across institutions and sectors. The information is organized by the previous section's thematic calls for reform, though most of these efforts cut across many, if not all, themes. Importantly, several approaches gaining national attention today have deep roots in the long-standing practices of Minority Serving Institutions (MSI). The call-out box in this section highlights how these institutions have modeled inclusive, student-centered, and socially engaged STEM education for decades.

Public Engagement and a Growing Field of Civic Science

Early responses to calls for public-engagement skills have begun to shift how STEM graduate students are trained. Universities, federal agencies, professional societies, and nonprofit organizations have offered new trainings.

Universities are increasingly developing for-credit science communication opportunities for graduate students. For example, the University of Arizona launched a Science Communication Graduate Certificate open to graduate students and postdoctoral fellows. The program aims to equip future science professionals with the skills to communicate their work clearly and effectively with diverse audiences.[3] Similarly, Stony Brook University offers an Advanced Graduate Certificate in Science Communication through its Alan Alda Center for Communicating Science, providing a 12-credit, for-credit program focused on evidence-based public engagement and audience-centered communication for STEM graduate students.[4]

At the federal level, the National Science Foundation (NSF) has recently funded several initiatives focused on public engagement. The University of Cincinnati's Center for Public Engagement with Science (PEWS) received NSF support to develop an interdisciplinary educational sequence that includes new coursework, internships, and research evaluating the impact of this training.[5] Similarly, the University of Wyoming, in partnership with American University, Colorado State University, and the University of Denver, was awarded a five-year, $1 million NSF Innovations in Graduate Education grant to launch "SciComm LIFT," which will pilot and rigorously evaluate new ethical science communication training models for STEM graduate students (University of Wyoming, 2024).

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[3] For more information, see https://science.arizona.edu/graduate-certificate-science-communication.
[4] For more information, see https://www.stonybrook.edu/commcms/journalism/graduate-students/science-communication-certificate.php.
[5] For more information, see https://ucengagingscience.org/2022/09/08/nsf-funds-uc-graduate-training-in-public-engagement-with-science/.

Professional societies and nonprofit organizations also play a critical role by offering experiential learning opportunities. The Thriving Earth Exchange Community Science Fellows program, run by the American Geophysical Union, trains graduate students and other scientists to collaborate with communities on projects that address locally defined environmental challenges (American Geophysical Union, n.d.). The National Science Policy Network (NSPN), founded in 2018, supports early-career scientists in engaging with policy through training, resources, and a nationwide community (National Science Policy Network, n.d.). Meanwhile, Research!America's Civic Engagement Microgrant Program, launched in 2018, provides up to $4,000 for graduate student-led teams to create outreach projects that foster dialogue with public officials, local leaders, and communities around shared concerns (Research!America, n.d.).

Over the past decade, these efforts to move scientists beyond the lab and into direct engagement with the communities their work impacts have begun to coalesce into a broader movement. As Mariette DiChristina, dean of Boston University's College of Communication, put it: "The movement goes by many names, but one stands above the rest: civic science" (Chalufour & Callahan, 2025).

One of the most visible efforts to institutionalize civic science has been the creation of the Civic Science Fellows program, launched in 2019 by the Rita Allen Foundation in collaboration with many other major funders. The program embeds emerging leaders within organizations working at the interface of science and society to lead projects in community-based research, public dialogue, and institutional change. While not focused exclusively on graduate students, Civic Science Fellows often develop programs and resources that support early-career scientists or partner with universities to expand civic science training. By 2024, more than 40 partner organizations had hosted Fellows, contributing to a growing network of professionals advancing inclusive, publicly engaged scientific practice.

These efforts complement growing university-based programs to embed civic science principles directly into graduate curricula. For example, the Scientific Citizenship Initiative (SCi) was originally founded at Harvard University to integrate civic science training into STEM graduate education through "transformative classroom trainings and a pioneering summer fellowship program that empowered scientists to serve society directly" (Scientific Citizenship Initiative, n.d.). More recently, at Boston University, a new Graduate Certificate in Civic Science Communication offers a four-course sequence designed for a wide audience, including early-career scientists and graduate students, who seek to improve their ability to communicate research and incorporate public values into scientific inquiry. At Tufts University, the Civic Science Initiative within the Tisch College of Civic Life offers science-in-society courses for STEM graduate students that emphasize interdisciplinary collaboration and civic engagement. These and other programs treat public engagement not as an extracurricular activity, but as a core competency of scientific training.[6]

[6] For more information, see https://tischcollege.tufts.edu/programs-major/civic-studies-co-major-minors/civic-science.

Together, these developments reflect a meaningful cultural shift: preparing graduate students not just as researchers, but as civic-minded professionals capable of engaging diverse publics, navigating the societal implications of their work, and ensuring that science remains connected to democratic values. While the terminology may continue to evolve, the movement toward integrating civic science into graduate education is clearly underway, through curricular innovation, funding mechanisms, community partnerships, and growing support across the STEM enterprise.

Broadening Training Skills and Career Pathways

Recognizing that 21st century challenges demand more interdisciplinary and versatile scientists who are trained for a wide range of careers, many programs have introduced reforms to what and how graduate students learn.

At the federal level, the NIH and NSF spearheaded programs to expand career development opportunities. For example, the NIH launched the Broadening Experiences in Scientific Training (BEST) program from 2013 to 2019 at 17 institutions to pilot career exploration and professional development for PhD trainees (NASEM, 2018a). The NSF similarly created the Innovations in Graduate Education (IGE) program in 2015, which by 2025 has invested ~$43 million in 94 projects across 84 institutions to develop “bold, new, and potentially transformative approaches to STEM graduate training… that develop the skills, knowledge, and competencies needed to pursue a range of STEM careers” (National Science Foundation, n.d.-a).

Another major federal initiative is the NSF’s National Research Traineeship (NRT) program. The NRT program was established to modernize STEM graduate education by promoting innovative, interdisciplinary, and scalable training models that align with evolving workforce and research needs (National Science Foundation, n.d.-b). Since 2017, the NSF has also directly facilitated graduate internships through its INTERN supplemental funding, which provides over 250 PhD students per year up to ~$55,000 to do a 6-month non-academic internship at a company, government agency, or nonprofit (National Science Foundation, n.d.-c). Such efforts reflect a broad recognition that STEM PhDs require preparation for diverse careers in industry, government, policy, and beyond, not just academia.

Universities are also actively adapting their curricula to integrate modern technical skills and foster interdisciplinary collaboration. For instance, the University of Arizona has created Graduate Interdisciplinary Programs (GIDPs), which offer formal PhD and Master's degree majors and minors that transcend traditional disciplinary boundaries, fostering research and training that cannot be effectively conducted within a single department (University of Arizona Graduate College, n.d.). Meanwhile, Wichita State University offers a graduate certificate in interdisciplinary STEM education, aimed at educators and graduate students interested in designing and delivering interdisciplinary curricula, emphasizing real-world problem-solving and critical thinking.

Advancing Diversity, Equity, and Inclusion (DEI)

Over the past decade, STEM graduate education increasingly prioritized diversity, equity, and inclusion.

Through 2024, the U.S. federal government made substantial investments to promote diversity, equity, and inclusion (DEI) in STEM training. A flagship initiative was the NSF's Eddie Bernice Johnson Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES) Initiative, established in 2016 as part of NSF's "Big Ideas" framework (National Science Foundation, n.d.-d).[7] It aimed to broaden participation in STEM through collaborative infrastructure building. Meanwhile, the NIH Diversity Program Consortium (DPC) launched the Diversity (BUILD) Initiative, which supported a more diverse STEM graduate population by targeting "the loss of promising students…during undergraduate training and at the decision point to continue training at the graduate level" (National Institutes of Health, 2013).[8] In parallel, major funding agencies began requiring applicants for graduate training awards, such as NIH T32 grants, to include detailed diversity recruitment and retention plans (Lorsch & Gammie, 2019).

At the institutional level, many universities created new Diversity, Equity & Inclusion offices, particularly after the 2020 murder of George Floyd (Johnson, 2023). These offices typically worked to create equitable environments, prevent discrimination, and support the success of underrepresented students. Their activities included developing inclusive curricula, supporting mentoring programs, and offering professional development in areas such as cultural humility and effective networking.

Another major shift was the widespread elimination of the GRE, driven by evidence that it poorly predicted PhD success and disproportionately disadvantaged women and underrepresented groups (Auburn, 2019; Miller & Stassun, 2022). In 2018 alone, 44% of molecular biology PhD programs dropped the GRE, and by 2022, only ~3% of top-ranked U.S. science programs still required it (Langin, 2019; Langin, 2022). Outcomes have been positive. For example, after geoscience graduate programs eliminated the GRE requirement in 2019, several reported notable increases in both total applications and diversity; for example, Georgia Tech's School of Earth and Atmospheric Sciences saw underrepresented minority applicants rise from 6% to 13%, and offers to these applicants reach 23% (Popp et al., 2020). This shift was widely seen as reducing barriers to graduate study for students from diverse backgrounds.

Alongside admissions reform, professional societies led major initiatives focused on recruiting and retaining underrepresented students. For example, the Inclusive Graduate Education Network (IGEN), a national "coordination hub" for the NSF's INCLUDES effort, was launched in 2018 with a $10 million NSF grant and led by five scientific societies (American Physical

[7] The NSF's Eddie Bernice Johnson INCLUDES Initiative, and similar programs, are currently under review due to shifting federal priorities.
[8] The NIH Diversity Program Consortium, and similar programs, are currently under review due to shifting federal priorities.

Society, 2018). IGEN promotes inclusive practices, supports research on effective strategies, and builds cross-sector partnerships to boost degree completion among underrepresented students. As of 2023, 379 students have entered IGEN-affiliated Bridge Programs, with a 94% retention rate, and the initiative was projected to significantly narrow degree gaps in chemistry, geosciences, and physics (WestEd, 2023).

Foundations also invested heavily in diversifying STEM graduate education. The Sloan Foundation's University Centers of Exemplary Mentoring (UCEM) program, for instance, supported universities working to "transform STEM graduate education in ways that make it more welcoming and inclusive for all" (Alfred P. Sloan Foundation, n.d.). The aforementioned HHMI Gilliam Fellowships not only enhance mentorship (as discussed) but, prior to 2025, had the goal of ensuring "populations historically excluded from and underrepresented in science are prepared to assume leadership roles, including as college and university faculty, and to foster the development of a healthier, more inclusive academic scientific ecosystem" (Howard Hughes Medical Institute, 2021).

Enhancing Mentorship Quality, Student Well-Being, and Work Environment

Efforts to improve the graduate education experience require addressing the deeply intertwined issues of mentorship quality, student mental health, and working conditions. Poor advising can exacerbate mental health challenges; unmanageable workloads or financial stress can undermine both research and well-being; and power imbalances, whether in the lab or at the institutional level, can leave students vulnerable. Recent policy responses across multiple fronts reflect a collective effort to address these issues.

Mentorship reform has emerged as a cornerstone of this effort. In 2024, the NSF began requiring principal investigators to submit formal mentoring plans and report annually on each student's Individual Development Plan (IDP), tying advising quality directly to grant compliance (Palmer, 2024). Meanwhile, in 2014, the NIH-funded National Research Mentoring Network (NRMN), which included workshops designed to support mentors of biomedical researchers at all career stages, including graduate students (NRMN Staff, 2018). Building on that model, the Center for the Improvement of Mentored Experiences in Research (CIMER) launched in 2015 to develop research-informed workshops, rigorously evaluate their impact, and disseminate best practices nationwide to foster a culture of inclusive, high-quality research mentoring. Universities have also adopted campus-wide PhD mentoring policies that formalize expectations for advising relationships and create mechanisms for oversight and support (Johns Hopkins University, 2019). Foundations like HHMI have further professionalized mentorship through grant requirements and faculty training programs focused on inclusive, research-based practices (Howard Hughes Medical Institute, 2021). These efforts reflect a growing shift toward treating mentorship not as a personal style but as a skill to be taught, evaluated, and improved, a shift with clear implications for student success and well-being.

Graduate mental health has likewise become a focal point of reform. Over 150 universities have endorsed the Council of Graduate Schools and Jed Foundation's 2020 Statement of Principles on Graduate Student Mental Health, which urges institutions to provide tailored counseling, promote work-life balance, and train advisors to recognize signs of distress (American Public University System, 2021; Council of Graduate Schools & The Jed Foundation, 2021). Federal agencies have also taken steps to ensure safer training environments. For example, both the NIH and NSF have required institutions to report confirmed harassment by PIs, enabling agencies to remove offenders from grants, a measure that signals greater accountability and protection for trainees (National Science Foundation, 2018; American Association of Medical Colleges, 2022).

In parallel, the graduate student labor movement has reshaped the structural landscape of support. Unionization has surged following the 2016 National Labor Relations Board (NLRB) ruling affirming graduate workers' right to unionize (National Labor Relations Board, 2016). Between 2016 and 2023, union drives spread rapidly, particularly during 2022–2023 when over 33,000 graduate workers at 19 universities won recognition (Quinn, 2023). These unions have negotiated contracts that significantly improve pay, healthcare, child-care support, and grievance procedures. Notably, the University of California's 2022 strike, the largest in U.S. higher education history, secured a nearly 50% stipend increase, setting new national benchmarks for improved compensation (NPR, 2022).

Addressing Structural Incentives

Many of the reform efforts described earlier in this section, including improvements in mentorship, mental health, civic science training, and career pathways, have the potential to reshape structural incentives in graduate education. Rather than revisiting those initiatives, this subsection highlights a set of additional reforms that more directly target how students are funded, research roles are structured, and programs are held accountable.

One major shift involves new approaches to research funding. For example, the NIH's Maximizing Investigators' Research Award (MIRA), launched in 2015, consolidated multiple grants into a single, flexible award (Preusch, 2015). The NIH's Research Specialist Award (R50), launched in 2016 by the National Cancer Institute, provides stable five-year funding for professional staff scientist roles (Singer, 2018). These approaches have the potential to reduce the need for investigators to chase additional funding, allow more time for activities such as mentoring trainees, and limit over-reliance on graduate students and postdocs for routine research labor.

Improved transparency around graduate program outcomes is also beginning to reshape incentives. In 2017, the Association of American Universities (AAU) issued a policy statement urging all PhD-granting universities to publicly post data on their students' demographics, time-to-degree, financial support, and career outcomes (NASEM, 2018a). Shortly after, the Coalition for Next Generation Life Science (CNGLS) announced plans to publish comprehensive PhD outcome data online and now includes more than 39 research institutions committed to publishing standardized data on PhD admissions, demographics, time-to-degree, completion rates, and career outcomes (Coalition for Next Generation Life Science, n.d.). Similarly, the Council of Graduate Schools (CGS) undertook the PhD Career Pathways project (2017–2020) with support from private foundations, collecting data from 75 universities on the career trajectories of PhD alumni across all sectors (Council of Graduate Schools, n.d.). These transparency initiatives are filling an information gap and enabling evidence-based career guidance. Making these data publicly available enables prospective students to make more informed decisions and encourages programs to take responsibility for training quality and outcomes.

Collectively, these reforms suggest that structural change is underway, albeit unevenly, across the graduate education landscape. By incentives and providing transparency, stakeholders are beginning to build a system in which graduate student development is prioritized alongside research productivity.

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HBCUs, MSIs, and TCUs: Pioneers of Inclusive STEM Education

Many of the most urgent reforms now being called for in STEM graduate education, such as active mentorship, inclusive climate, holistic admissions, and alignment with societal needs, have long been core practices at Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs), and other Minority Serving Institutions (MSIs). While most of these institutions primarily serve undergraduates, the values and structures that support student success at MSIs are highly relevant to graduate education. Their long-standing approaches offer powerful, proven models for building more inclusive, student-centered, and community-engaged STEM training environments.

Though often underrecognized in national policy conversations, HBCUs, TCUs, and MSIs have played a vital role in the U.S. STEM ecosystem for over a century. Founded with explicit missions to educate communities excluded or underserved by predominantly white institutions, MSIs collectively enroll nearly 30% of all U.S. undergraduates and produce about one-fifth of the nation's STEM bachelor's degrees (NASEM, 2019). HBCUs in particular punch far above their weight: while representing only ~3% of colleges, HBCUs award roughly a quarter of all STEM bachelor's degrees earned by African Americans, and nearly one-third of Black science and engineering PhD recipients completed their undergrad at an HBCU (United Negro College Fund, n.d.). TCUs, for their part, serve as community-anchored gateways for Native American students, providing culturally attuned STEM programs on or near reservations (American Indian College Fund, n.d.). These institutions' intentional support of students historically marginalized in higher education has made them vital engines of diversity and opportunity in STEM—a point emphasized in analyses by the National Science Foundation and the National Academies (Wondwossen, 2020; NASEM, 2019).

In addition to these structural strengths, attendance at MSIs is associated with a range of direct positive outcomes for students. The 4-year graduation rates for Black undergraduates attending public and private HBCUs are 62% and 67%, respectively, compared to the 21% rate for Black undergraduates and the 44% for White undergraduates across all institution types (Shuler et al., 2022). Furthermore, there is evidence indicating that MSIs perform even better than federal graduation rates suggest when accounting for students on non-traditional graduation timelines (Espinosa et al., 2017). Students of color report both more welcoming campus cultures overall and greater feelings of inclusion within their specific STEM departments at HBCUs (Winkle-Wagner & McCoy, 2018). Black undergraduate men attending HBCUs also report fewer mental health conditions (Barry et al., 2016).

These positive outcomes associated with MSIs are not accidental. They are the result of intentional, mission-driven practices embedded in the structure and culture of these institutions. The following examples illustrate how the core values and practices of these institutions translate into concrete approaches that align closely with can inform national calls to reform graduate STEM training.

- Inclusive, Nurturing Culture: HBCUs have long cultivated academic environments built on encouragement and belonging rather than cut-throat competition. By developing university missions that affirm students' scholarship and their rightful place within higher education and ensuring that all university members, from students to faculty to support staff, have bought into their university's mission, these universities are able to create environments that “empower students, not weed them out” (Wondwossen, 2020).

- Holistic Mentorship and Support: At MSIs, faculty and staff frequently take on a multi-faceted mentoring role that extends beyond academics. Professors at HBCUs often provide one-on-one guidance, encouragement, and culturally informed advice, creating “safe and nurturing” spaces for students (Shuler et al., 2022). The faculty body itself is more diverse at many HBCUs, allowing students to be mentored by individuals who understand their backgrounds and can serve as relatable role models. This high-touch mentorship model – focused on each student’s personal and professional growth – is exactly what recent reform reports urge graduate programs to adopt in order to improve mentorship quality and student well-being.

- Culturally Relevant Education: MSIs have pioneered integrating students’ identities and values into STEM learning. TCUs, for example, weave Indigenous knowledge, tribal languages, and community priorities into science curricula, helping students see STEM as relevant to their lives and communities (Bryan, 2018). Likewise, many HBCU and Hispanic-Serving Institution (HSI) instructors incorporate diverse perspectives and historically underrepresented contributions to STEM, which helps foster a sense of belonging for minority students. These practices mirror calls for graduate programs to better address equity and inclusion by valuing diverse perspectives and creating welcoming climates.

- Career and Community Orientation: HBCUs and other MSIs have a tradition of preparing students for real-world success in STEM careers, not just academia. Curricula at these schools tend to be adaptable and practice-oriented, and many programs encourage undergraduates to engage in internships or research addressing community needs (Darby, 2024). This aligns with modern calls for graduate education to broaden career training and public engagement. The longstanding expectation at MSIs that science should ultimately serve communities (e.g., via improved health, education, or environmental outcomes) also anticipates today’s emphasis on the societal and ethical responsibilities of scientists.

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Recent Federal Shifts Impacting STEM Graduate Education

The Trump administration's 2025 policy agenda has introduced significant changes that will reshape the landscape of STEM graduate education in the United States. These efforts reflect significant pivots from longstanding support for academic institutions, spanning deep funding cuts, rollbacks of diversity, equity, and inclusion (DEI) programs, increased visa restrictions, and federal measures aimed at compelling university policy changes. While many of these actions are being challenged in court, the administration is already advancing key aspects of its agenda through agency action and executive authority, resulting in significant immediate impacts.

A central feature of this agenda is the FY2026 federal budget proposal, introduced by President Trump in early 2025. While presidential budgets are not binding and require congressional approval, the proposal signals the administration's priorities. It includes a more than 50% reduction to NSF and a nearly 40% cut to the NIH, alongside significant reductions at other science and education agencies, including NASA, the Department of Energy, and the Department of Education (Agarwal, 2025). These proposed cuts have already had an observable impact on STEM graduate students. For example, MIT has already cut its biology PhD program admissions by 20% due to budget uncertainty (Hir, 2025). If fully enacted, these cuts could result in the elimination of more than 80,000 research jobs, further limiting the job prospects available to STEM graduate students (The Economist, 2025).

In addition, the tax-and-spending bill enacted in July 2025 (H.R. 1) included several changes specifically targeting graduate education. For example, the bill eliminated the federal Grad PLUS loan program, which currently supports a significant share of graduate borrowers, including about 20% of master's students and roughly 25% of STEM graduate borrowers who use student loans. The impact of this change will be disproportionately felt by minority-serving institutions: of the nearly 1,800 schools whose students used Graduate PLUS loans last year, nearly one in five is a federally designated MSI, and about two-thirds of those primarily serve Hispanic communities (Will, 2025).

The administration is also pursuing its priorities through executive orders, which has led to several immediate effects. For instance, more than 1,000 NSF grants have been canceled, including 400+ directly tied to STEM education research (Schwartz, 2025). In 2025, the number of NSF Graduate Fellowships was reduced from approximately 2,000 to 1,500 (Zhang, 2025).[9] NSF is exploring new partnerships with private industry and philanthropic organizations to support additional graduate fellowships.[10] While still in its early stages, this effort may indicate an interest in identifying alternative funding models in the face of reduced federal support.

A significant share of the canceled NSF grants was concentrated in STEM education and workforce development programs, many of which were focused on DEI efforts. This pattern aligns with a broader shift in agency priorities following a May 2025 executive order titled Restoring Gold Standard Science that further directed federal agencies to eliminate funding for programs the administration described as 'politicized,' specifically naming DEI and climate-related efforts (White House, 2025). These changes have resulted in the elimination of programs that previously supported broader participation in STEM fields, including undergraduate research opportunities, graduate fellowships, and mentoring initiatives. The reduction in such programs may affect access to graduate education for students from a wide range of backgrounds and could influence the future composition of the scientific workforce.

Reflecting broader shifts in federal DEI policy, the NIH has also removed several longstanding requirements related to diversity reporting and consideration in its institutional training programs. As of 2025, NIH no longer requires Recruitment Plans to Enhance Diversity in T32 training grant applications, and such plans are not considered during peer review or funding decisions (National Institutes of Health, 2025). Additionally, institutions are no longer required to submit Trainee Diversity Reports as part of annual progress reporting, and the ability to generate these reports has been discontinued. These changes reduce information on the demographic composition of trainee populations and mark a significant departure from earlier federal efforts to strengthen diversity in the biomedical research workforce.

The administration also has taken steps that increase federal scrutiny of university policies, with particular consequences for international students and academic researchers. In April 2025, the Department of Homeland Security notified Harvard University that it risked losing its certification under the Student and Exchange Visitor Program (SEVP), a move that could affect approximately 6,800 international students, unless the institution complied with requests related to student disciplinary records and policies on campus protests and antisemitism (Bianco & Quilantan, 2025). A federal judge later issued a preliminary injunction blocking the action, citing concerns about

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[9] The National Science Foundation announced an additional 504 NSF GRFP recipients on June 13, 2025 on top of the 1,000 awardees announced in April 2025. See https://cen.acs.org/policy/research-funding/NSF-names-504-new-graduate/103/web/2025/06 and https://cen.acs.org/policy/research-funding/NSF-halves-graduate-fellowship-awards/103/web/2025/04.

[10] For news regarding new approaches to the NSF graduate fellowships program, see https://www.aip.org/fyi/nsf-seeks-partnerships-to-fund-graduate-fellows.

retaliation and potential violations of constitutional protections. These developments have prompted concerns about potential impacts on international student participation and the broader climate for research and scholarly exchange.

While the long-term outcomes of these proposals depend upon ongoing congressional and judicial actions, their cumulative effects are already disrupting the nation's STEM graduate education system. What was once regarded as a global model of excellence and innovation is increasingly marked by financial austerity, reduced inclusivity, and politicized interference. Without significant course correction, these developments could undermine the nation's capacity to train, attract, and retain the next generation of scientific leaders.

Building on Strength, Moving with Purpose

For more than a century, U.S. STEM graduate programs and students have been the critical enablers of discovery that gave the world polymer chemistry, the microchip, the internet, and, most recently, mRNA vaccines and generative artificial intelligence. Their combination of disciplinary depth, hands-on apprenticeship, and sustained federal investment has trained generations of researchers whose breakthroughs fuel economic growth, national security, and public well-being. These accomplishments demonstrate what becomes possible when we invest in talented people and bold ideas. Yet the very forces our system helped unleash now call for an updated playbook.

As scientific research increasingly shapes our economies, communities, and daily lives, graduate education must evolve beyond technical training to prepare scientists who can engage ethically and effectively with society. This includes equipping trainees with the tools to communicate across diverse publics, respond to real-world needs, and reflect on the broader implications of their work. As discovery accelerates through AI and interdisciplinary convergence, our training systems must keep pace, expand access, strengthen mentorship, and build more inclusive, supportive pathways into science. Meeting this moment will require not just new programs, but a rethinking of the institutional structures that shape how science is taught, practiced, and valued.

The past decade has seen unmistakable momentum towards these goals. Programs that prepare scientists to communicate with broader audiences and responsibly engage with society have been flourishing, giving rise to a growing field of civic science. New curricula and experiential programs emphasize interdisciplinary learning and real-world practice, preparing students for a wide range of scientific and non-academic careers. Coordinated efforts across agencies, institutions, and professional groups aim to widen recruitment, foster inclusive climates, and hold programs accountable for equitable outcomes, even as such commitments face intensifying political and legal challenges. Professionalized mentoring, strengthened mental-health supports, and improved labor conditions are converging to create healthier, more supportive training environments. The collective impact of these measures, along with evolving funding models and increased transparency of program outcomes, are realigning incentives and laying the groundwork for a graduate education system that better serves science, scientists, and society.

While recent reforms reflect growing momentum, progress remains uneven, and the work of transformation is still underway. Many promising reforms remain at the pilot stage or are implemented unevenly across institutions. Moving from promising pilots to systemic change will require sustained investment, coordination, and creativity, alongside long-term commitment, structural alignment, and a readiness to reassess what graduate education must look like to meet evolving demands. Achieving lasting change will also demand persistence, coordination, and the courage to confront entrenched systems.

Fortunately, there is a remarkable community of educators, students, policymakers, and institutional leaders who continue to drive reform across the STEM ecosystem. Despite limited time, recognition, or funding, these champions have shown deep commitment and creativity, often advancing change in ways that fall outside traditional reward structures. Their collective energy and determination underscore a simple truth: while the work is hard, the will to reimagine graduate education is already here.

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