SPECIAL SECTION

Higher Education Reimagined

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Critical Steps Toward Modernizing Graduate STEM Education

Maintaining US leadership in graduate STEM education will require a focus on a wider range of skills beyond those needed for academic research.

The US system for graduate education in science and engineering is widely regarded as the best—or at least among the best—in the world, as evidenced in part by the many thousands of students from other countries who come to the United States each year for their graduate training. At the same time, there is wide recognition that in many institutions the US model of graduate education has failed to stay current with trends in the way science is conducted and with the nature of the student population and their career interests and opportunities. In fact, since a major report by the National Academies of Sciences, Engineering, and Medicine in 1995, over 20 studies and reports on graduate science, technology, engineering, and mathematics (STEM) education have come to that same conclusion: graduate STEM education in the United States needs to be modernized. The changes recommended in these studies have been quite consistent, and include the need to create a more inclusive and equitable environment to enable all members of a very diverse student population to thrive; to improve the quality of teaching, advising and mentoring; and to modernize the curriculum and capstone projects to better focus on core competencies and better reflect the way science is now being done.

Why has there been so much inertia in the system, and what needs to be done and by whom to help make the graduate STEM education system move forward? We were recently involved in a new National Academies report—*Graduate STEM Education for the 21st Century*—which directly confronted these questions.

This report differed from the many earlier reports in that it laid out what would constitute an ideal graduate STEM education and an action plan for achieving that ideal, including specific steps to be taken by all stakeholders. We here discuss some of its major points, including what is needed to stimulate system change at a national level.

Central to making any pervasive change in STEM graduate education will be significant attitudinal, behavioral, and cultural changes throughout the system. The ways that faculty approach graduate education must be fundamentally reoriented to include a greater focus on the interests and needs of the students. The purpose of graduate education can no longer be exclusively, or even predominantly, to produce more academic researchers. Graduates today are using their training to pursue a much wider range of careers than in the past, and the nation needs well-trained scientists in government, industry, and other settings. The fundamental skills needed in all these settings are basically the same—broad technical literacy as well as deep specialization in an area of interest, an understanding of the ethics and norms of the enterprise, and the ability to communicate findings both to colleagues and the broader public. However, in addition to these capabilities, students need to learn about or at least become familiar with the wider range of skills needed in the nonacademic settings where they want to work, so less retraining is needed when they get there.

An ideal graduate program

What would an ideal graduate education look like, and what actions need to be taken to begin to approach that ideal? In the first place, graduate programs should publish very clear data about the outcomes and career paths of their alumni, so that prospective students can make more informed and relevant choices about where to go to graduate school. The ideal program would then provide opportunities in the first year for students to sample a variety of laboratories and mentors before they make final choices about what professors they should work with. Higher education institutions should provide training for all prospective mentors and advisers, and retraining when needed for current faculty, to ensure students have appropriate and consistent faculty support. Opportunities such as internships, special courses, and professional development activities would be provided for students to learn what it might be like to pursue a career in a nonacademic setting—in business and industry, government, and the nonprofit sector. Particular attention would be paid to the needs of students from diverse backgrounds, and they would be educated in inclusive and equitable environments that maximize the probability of their success. Institutions would increase availability of mental health services and similar supports for students and would provide faculty, administrators, and leadership with strategies to improve campus environments and do a better job fostering success for all students.

Central to achieving this proposed ideal STEM graduate education is the concept of "core competencies"—the skills and knowledge base that are the essence of what it means to be a master's or doctoral graduate, competencies that all students must achieve, no matter what their career goals or interests might be. These core competencies would be the main focus of graduate education, with other experiences and coursework supplementing them. For master's students, the core competencies include a foundation in the content and research practices aligned with the student's disciplinary focus, as well as a set of transferrable, professional skills. Examples of core competencies at the doctoral level include, as one might expect, both broad and deep scientific and technological literacy and the ability to do original research. The core competencies would also include a set of leadership, communication, and professional skills, including an understanding of the norms and values of the STEM enterprise and the ability to communicate both to one's peers and to the broader public community.

Students would gain experience working in teams, preferably multidisciplinary teams, since that has become so typical of modern scientific research. Moreover, dissertations or capstone projects might well take different forms—for example, using narrative or multimedia approaches—again to better reflect trends in both modern science and professional opportunities.

Local control makes systemic change difficult

There is a good reason that 25 years of agreement about the need for graduate STEM education reform has yielded such little progress: cultivating change across a broadly distributed system is hard. Like virtually all US higher education, STEM graduate education is locally controlled, both at the institutional and even the departmental level. Importantly, and as it should be, the curriculum is controlled at the level of the faculty, and top-down attempts to order changes in curricula from academic leaders have typically been failures. Although there are some constants within graduate schools, such as the apprenticeship or mentorship model that seems pervasive, no single body controls what goes on across all of them. There is no set of rules that prescribes exactly what graduate programs will look like. There is national accreditation, but also great diversity both across and within institutions. That variation is both a strength and a limitation. The diversity among programs allows for adaptation to the local context and unique characteristics of departments, disciplines, and their individual faculties. It is also a limitation in that "no one is in charge": if there is a need for change, there is no body or organization that can dictate the nature of change across the system. Faculty do learn from their own graduate experiences and then from colleagues in other departments and institutions, but ultimately the lack of any controller makes it very difficult to move the system into new directions.

Academic incentives are critical

What makes achieving the ideal particularly difficult is that the incentives that currently drive so much of academic culture and faculty behavior are misaligned with achieving the goals outlined in the National Academies' report. Criteria for promotion and tenure typically are too heavily weighted toward research productivity in the form of publications in prestigious journals and research grants received from federal agencies, with far too little emphasis given to the quality of graduate student teaching and mentoring. The balance between research activities and education and mentorship must be readjusted to give more emphasis to quality education. Doing so would also provide a mechanism for more appropriately rewarding those faculty who have consistently dedicated significant attention to the development and growth of graduate students, at times at a cost to their own research productivity. This would be a radical change for many institutions, and it will come about only with clear commitment from every level of the university, including the president, provost, graduate dean, and other administrative leaders, and including all levels of the faculty, particularly department heads and promotion and tenure committees.

Yet academic incentives are not solely under the control of academic institutions because the state and federal agencies that fund academic research and training also often employ granting criteria that are biased against the sorts of changes we are advocating, even for purported education and training grants, and these criteria significantly influence faculty behavior. Grant review criteria—and, frequently, peer reviewer behavior whatever the stated criteria—typically emphasize the traditional research productivity measures, such as number of papers published, numbers of citations, and journal impact factor. Faculty looking for grant support, understandably, then respond by focusing their efforts most heavily on producing and publishing research results, at times at the expense of their educational responsibilities. To help modernize the system, funding agencies will need to realign their award criteria, particularly for training grants, but also for research grants that include support for graduate research assistants, to give more emphasis to the quality of teaching and mentoring. Such realignment is entirely consistent with the missions of government agencies that fund graduate STEM research, which always include a commitment to assuring that the nation has a vibrant future STEM workforce. Adjusting the weights assigned to their funding criteria would have a domino-like effect on incentives employed throughout the higher education system.

The student-mentor relationship is critical

The quality of all students' graduate experience depends highly on the nature of their relationships with their mentors and other advisers. The National Academies committee that produced the new STEM report held focus groups and met with many graduate and postdoctoral students during its work. Those discussions revealed great variability in mentor relationships. Although some students reported positive experiences, many cited relationships ranging from benign negligence to well-intentioned yet ultimately unsupportive behavior to more problematic and frustrating behaviors. Too often students felt as if their mentors saw them as employees or research technicians, rather than as students they had a responsibility to serve. As harsh as such criticism may seem, it is not surprising, given that the academic incentive system is so heavily weighted toward research productivity and against quality mentorship. The mentors and advisers who commit themselves to providing quality guidance to their students often do so without their efforts being counted toward promotion, tenure, grants or other funding, and general career advancement and recognition.

But better mentoring is not just a matter of incentives; it is also a question of skill, and fortunately effective student mentoring is a skill that can be taught. Of course, some people are naturally more empathetic and nurturing than others, but those traits are not enough. Mentors need to be willing and able to teach effectively and to advise their students on career paths and opportunities. Because better mentoring can be learned, higher education institutions should require formal training for all new mentors and provide ongoing professional development for those more experienced mentors who seem to need it.

Incoming graduate students, in turn, should be exposed during their first year to multiple laboratories and mentors, before they are required to choose among them for the rest of their graduate programs. Many institutions are now doing this, and they and their students report great satisfaction with this approach.

Diverse, inclusive environments are essential

Graduate institutions must also ensure that they are providing a learning environment in which all students can thrive. Over the past decades there has been a major shift in the student population, with more women and members of underrepresented minorities interested in joining the scientific workforce. However, many women and minority students report that they do not feel included in the same way as are men or nonminority students. Faculty and administrators need to develop, implement, and continually assess strategies, starting with admissions policies, that not only increase diversity and inclusion of graduate students but also assure retention of such students throughout the process of achieving an advanced STEM degree.

Real change requires a systems approach

Modernizing graduate STEM education will require a systems approach that includes actions from each relevant member of the system. For example, all institutions and departments should collect and make easily available data on student outcomes and career paths, so that incoming students can select their graduate programs in an informed way. Faculty should regularly reevaluate the curriculum to ensure it accurately reflects the way science is currently conducted in their field. Departments should also ensure they are providing students with a full array of core competencies necessary for professional development and examine carefully what might be extraneous course requirements that may not really matter to eventual success as a scientist. Employers from all sectors should engage with higher education institutions to help them shape curricula and other educational experiences to maximize their effectiveness in preparing graduate students for future careers. And graduate students should themselves seek opportunities to work in cross-disciplinary teams that promote multidisciplinary learning, team collaboration, and a variety of problem-solving approaches.

Change is under way

Fortunately, institutional stakeholders in graduate STEM education have started working intensively to improve the enterprise's capacity to serve students and the national interest. For example, the National Institutes of Health's National Institute for General Medical Sciences updated its training grant solicitation to have a greater focus on students and on encouraging the development of skills for careers in the broad biomedical research workforce. Its requirements are consistent with our recommendations. More recently, the National Science Foundation sent out a "Dear Colleague Letter" announcing a program that enables any graduate student it funds to apply for supplemental support for exploring career opportunities in any sector to "ensure graduate students are well prepared for the 21st-century STEM workforce." Private funders, such as the Howard Hughes Medical Institute, have also made changes to support a more student-centric graduate education experience with a focus on increasing mentoring resources, training, and requirements for faculty fellowships.

The Association of American Universities in December 2017 announced the PhD Education Initiative to ensure that diverse career pathways are "visible, viable, and valued" through shifts in the culture of graduate departments, increase the transparency and use of PhD program data, and share effective practices among its member institutions. Twenty-nine members of the Council of Graduate Schools have joined the Understanding PhD Career Pathways for Program Improvement effort, in which participating institutions collect data from current students and alumni to understand career trajectories. The aim is for those data to inform incoming graduate students on the professional development and career services provided on each campus. Universities participating in the Coalition for Next Generation Life Science, an agreement of nine research universities and a cancer institute to improve transparency and trainee outcomes in the life sciences, have committed to publishing data on life science PhD and postdoctoral programs, with an added emphasis on postdoctoral researchers. The coalition is also emphasizing career support for diverse career paths, improved doctoral and postdoctoral mentoring, and improved diversity and retention of life sciences graduate students.

These ongoing efforts are a significant start on modernizing the system, and they reflect an encouraging, growing recognition of the need for reform. However, the changes these efforts will produce will inevitably be small relative to the scale of the entire graduate education system. Many more such efforts will be needed to make pervasive system change that can push graduate STEM education toward the ideal that we have outlined here. If we were to select the one set of actions that could most effectively catalyze such pervasive change, it would be for state and federal funding agencies to adopt funding criteria that can help shape academic incentives and culture. We realize that the necessary changes will not be easy to make, and that they will require new investments in both money and human resources, but these are the costs of assuring both graduate student success and the future of the United States' STEM enterprise.

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Securing the Future of the US Biomedical Research Workforce

After decades of hand-wringing but little action, a workable plan to improve biomedical research career pathways is coming into focus.

Since the end of World War II, the United States' preeminence in biomedical research has been widely recognized. There are a number of features of the US system that are responsible for its success, but surely one of the most important was the early embrace of high levels of federal research investment, coupled with the allocation of funds on a competitive, peer-reviewed basis. This trait is credited with helping the nation create a vibrant and innovative ecosystem for the advancement of knowledge and the human condition, and the US system has been emulated throughout the world.

Yet for all the biomedical research enterprise's many strengths, there are growing concerns that it is starting to slowly unravel—that its incentives are coming out of balance, with unsettling consequences for the researchers in the system, and in particular for the incoming generations of scientists.

The problems are many, and interwoven: The cost of conducting research has steadily risen, and the size of federal research awards has not kept pace. At the same time, the biomedical research workforce is aging, and a shrinking percentage of federal research grants are awarded to young scientists, who often spend many years in postdoctoral positions characterized by low pay and no guarantee of mentorship or career development. Although the graduate student and postdoctoral population in biomedical research has grown, there has been no growth in the number of academic faculty research positions, for which many of them have trained. These concerns are magnified by the lack of comprehensive counseling and mentorship for research careers in nonacademic settings.

Meanwhile, the system has been subject to intense criticism for its lack of success in diversity recruitment.

These issues are well-rehearsed. Over the past two decades, numerous commissions, task forces, and individual scientists have issued warnings of these vulnerabilities in the biomedical research workforce. As far back as 1994, a committee convened by the National Research Council traced the outlines of several of these problems in a report titled *Meeting the Nation's Needs for Biomedical and Behavioral Scientists*. In 2005, a National Academies panel issued the report *Bridges to Independence: Fostering the Independence of New Investigators in Biomedical Research*, which described how these emerging trends were creating special problems for early-career investigators—and even at that point it identified a "history of concern for these issues." In 2014, four prominent biomedical scientists again sounded the alarm in a highly influential journal article, titled "Rescuing US biomedical research from its systemic flaws," that called out a "severe imbalance" in a system that was "on an unsustainable path"

Each step of the way, the reports sounded calls for action and specified recommendations for reform. And yet, a great many of the recommendations went unaddressed. And the challenges endured, and in some cases, worsened.

Time to act

These same challenges have now drawn congressional attention. In the Consolidated Appropriations Act of 2016, Congress called on the National Academies of Sciences, Engineering, and Medicine to conduct a comprehensive study of the policies affecting the next generation of researchers in the biomedical sciences. The legislation, sponsored by Senators Susan Collins (R-ME) and Tammy Baldwin (D-WI), specified the creation of an expert committee to produce "recommendations for the implementation of policies to incentivize, improve entry into, and sustain careers in research for the next generation of researchers." Two of the authors of this article served as the chair (Daniels) and study director (Lida Beninson) of the committee convened to address these problems.

Early in the committee's deliberations, we wrestled with the question of why the problems had persisted in the face of earlier investigations and recommendations. We observed a time-honored propensity of many of the stakeholders in the system to discount their own role in the persistence of these problems and to instead ascribe to the federal government—particularly the National Institutes of Health (NIH)—the singular responsibility for reform. We found that declining resources at a time of austerity had left less opportunity for investment in policy reform or experimentation. We found that the highly distributed nature of the stakeholders in the sector had made it all the more challenging to address the entrenched problems, which often implicated actors in every part of the system. And we found that there was simply no structure or tradition of the sort of sustained, collective problem-solving across the sector that was needed to meet these problems. Indeed, we noted that stakeholder engagement on these issues has been episodic over the years, with working groups and expert committees often disbanding after issuing their recommendations.

Our careful review of prior recommendations found that whereas NIH and other federal actors had been at least somewhat responsive to earlier calls for reform, other entities had been less so. For instance, multiple reports over the decades had urged stakeholders to collect and make available data on the outcomes of graduate students and postdoctoral researchers. Among other steps, NIH started tracking postdoctoral researchers participating in its funded grants, automated the tabulation of data on trainees on training grants, piloted with the National Science Foundation a new survey on early-career doctorates, and created an office to collect and analyze biomedical research workforce data. But with a few exceptions, the committee found that there had been little to no meaningful action on these recommendations on the part of universities and other research institutions.

After a year of intense deliberations, the committee in 2018 issued its report, *The Next Generation of Biomedical and Behavioral Sciences Researchers: Breaking Through*. It offered a range of recommendations in response to specific challenges in the system. We called on Congress to increase NIH's budget to enable it to boost support for early-career researchers by expanding existing awards or creating new competitive awards for trainees and early-stage researchers to establish and advance their own independent investigations. In support of prior recommendations, we urged NIH to require principal investigators and research institutions to provide comprehensive and disaggregated data on postdoctoral researchers. The committee recommended that NIH conduct pilot studies to assess the feasibility of implementing a cap on the number of years of support that postdoctoral researchers can receive from NIH research project grants. We also recommended that NIH use its institutes and centers as vehicles to pilot new mechanisms designed to support the independence of early-career researchers

But we went further, calling for an overarching change in the approach to the biomedical enterprise. For too long, research universities, research centers, philanthropic foundations, private industry, and the federal government had worked at arm's length on questions of training, incentives, and funding rules that touch them all, and true reform would require sustained and collective action by actors across the sector. Our committee decided that to address such broad, ongoing challenges, as well as future challenges across the biomedical research enterprise, the nation needed a forum for sustained coordination, problem-solving, and assessment of progress. We thus proposed the creation of a public-private Biomedical Research Enterprise Council (BREC).

Design of the BREC should be guided by several broad, but not overly prescriptive, principles. First, the council should include representatives from federal agencies, research institutions, industry, disciplinary societies, nonprofit organizations, and foundations and philanthropies. Second, it should be an independent, nonprofit entity, so that it could be a fair interlocutor across the sectors. Third, the federal government might help to create and incubate the council in its early days: Congress might authorize the council, and NIH could provide early financial support for a modest support staff and initial convention. Finally, the BREC should eventually transition to a self-supporting model of funding with contributions from participating members.

The BREC will be a forum to conceptualize and develop ideas and policies to support the biomedical research workforce, share metrics and information, convene workshops to develop multisector strategies, and evaluate implementation on policy reforms. Additionally, it could work to anticipate future trends and needs in the biomedical enterprise and produce reports summarizing their activities and assessments. Ultimately, the council would work to build collective solutions to accelerate the pace of change needed to bring security to the biomedical research workforce.

Proof of concept

Public-private multistakeholder bodies akin to the concept of a BREC already operate successfully in other sectors. One example is InfraGard, a partnership among the Federal Bureau of Investigation, state law enforcement, academia, industry, information technology security professionals, and a range of others, in which they collaborate and share information to protect the nation's critical infrastructure.

The Smart Grid Interoperability Panel, launched by the National Institute of Standards and Technology, is another example. Designed to coordinate standards development for smart grids, the panel connects public and private stakeholders to interact and accelerate standards harmonization, advancing the interoperability of smart electric grid devices and systems.

Recently, however, a new model has emerged that only strengthens the promise of the multistakeholder approach to reform but could even serve as a vehicle for a BREC-like body moving forward. About two years ago, the National Academy of Medicine began to establish what it called "action collaboratives" to meet the clear need for a coordinated and collective response to pressing national challenges. These collaboratives would be flexible and action-oriented, built on the recognition that the relationship among multiple stakeholders is central for systems-level change.

In its first effort, the academy in 2017 launched an action collaborative on clinician well-being and resilience, with over 60 member organizations that were committed to developing and advancing multidisciplinary solutions to reduce clinician anxiety, burnout, depression, stress, and suicide. The academy followed this up with the launch in 2018 of an action collaborative to counter the US opioid epidemic. It includes over 35 organizations from across government, local communities, health systems, provider groups, payers, industry, nonprofits, and academia to share knowledge and align efforts to drive multisector solutions.

The action collaboratives show that it is possible to assemble the necessary public and private stakeholders around a common problem and sustain those collaborative efforts over an extended period in service of the national good. They are demonstrating that a systems-level approach involving a range of public and private actors can help to make progress on some of the nation's most intractable problems. For the BREC to work, representatives of government, the biomedical and pharmaceutical industry, nonprofit organizations, philanthropists, professional associations, scientific societies, and academia would need to come together to openly acknowledge and jointly confront unmet challenges such as optimizing postdoctoral training and mentoring, collecting comprehensive and disaggregated data, and aligning multisector priorities. The National Academy of Medicine's action collaboratives demonstrate that this is possible and sustainable if there is conviction of the need for action on a nationwide problem.

With proper incentives, sufficient resources, and coordinated efforts, the United States can ensure its ability to cultivate a cadre of scientists who will work to improve the health, well-being, and prosperity of people around the globe. It is time to adopt long-term structures and conditions to both initiate and sustain change so that the need for episodic task forces and reports that detail stasis and inactivity are replaced with ongoing and enduring change across the research enterprise. It is time to break through on these decades of persistent problems—not only for the next generation of researchers, but the generations to follow.

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LEIGH MILES JACKSON AND TOM RUDIN

Minority-Serving Institutions: America's Overlooked STEM Asset

Postsecondary institutions with an intentional focus on educating nontraditional students and students of color are a crucial part of solving the nation's STEM workforce supply problem.

Much has been written—including in this edition of *Issues*—about the STEM workforce needs of the future, both in the United States and globally. As the needs of modern business and industry become more complex, more jobs require at least some competency and literacy in science, technology, engineering, and mathematics—the STEM disciplines—and fields not traditionally defined as technical, such as design and law enforcement, have begun to shift into new STEM-related categories. Workforce projections anticipate that opportunities in STEM and related fields will continue to be in demand and will outpace the growth of other positions in the coming years.

Meanwhile, by the middle of this century, people of color will constitute roughly half of the US population, a transition toward a non-white majority that is all the more apparent when considering the demographic makeup of younger generations. In 2016, nearly half of the population 17 years of age or younger were people of color. By 2060, the proportion will be roughly two-thirds.

This convergence of labor market and demographic trends means that the educational outcomes and STEM readiness of African American, American Indian, Alaska Native, Hispanic, underrepresented Asian American, and other students of color will have direct implications for US economic growth, national security, and global prosperity.

As a standing principle, the nation has a responsibility to direct the necessary funding, attention, and support to the strategies that best advance the education and workforce preparation for the next generation. To fulfill that responsibility, it has become critical to understand how the nation's demographic profile is changing and what those changes mean for public policies and practices.

Today's higher education system evolved to serve the demographic profile of students enrolling in college two generations ago—mostly white, majority male. This profile is changing in part because of the rapid rise in the number of students of color graduating from US high schools. But it's also changing because more college students are nontraditional—independent, are parents, are single caregivers, lack a standard high school diploma, work full time, or attend school part time. Anyone who worries about the future of the STEM workforce should also be worrying about these trends, because today the nation's fastest-growing population groups, with the greatest employment potential, are also the most underrepresented across the entire STEM workforce.

And although the challenges tied to supporting the new profile of students in higher education are complex, including the need to reexamine every institution's current social, financial, educational, and cultural support systems, one obvious solution is to invest in institutions that already have an established record and focus on educating and training students who are underrepresented in STEM. Specifically, the nation should turn to its roughly 700 two- and four-year Minority-Serving Institutions (MSIs) and invest additional funding, attention, and support to help bolster the long-term success of the tens of millions of enrolled students. In support of this strategy, the National Academies of Sciences, Engineering, and Medicine in December 2018 issued the consensus study report *Minority-Serving Institutions: America's Underutilized Resource for Strengthening the STEM Workforce*.

Overlooked, underappreciated

Outside the education sector, many people seem to be unfamiliar with MSIs—what they are, who attends them, and when, why, and how they are designated as MSIs. Many education advocates believe that a lack of basic understanding about these long-established institutions is due in part to society's historical neglect of minority-related issues and challenges. Regardless of the reason, for years, MSIs' contributions to STEM education and efforts to train the nation's workforce have been largely overlooked and underappreciated.

Yet MSIs enroll nearly 30% of all undergraduates in the United States. In terms of their contributions to STEM education, more undergraduate students (from all backgrounds) are enrolled in STEM fields at four-year MSIs than at four-year non-MSIs, and when taken together, Historically Black Colleges and Universities, Hispanic-Serving Institutions, and Asian American and Native American Pacific Islander-Serving Institutions produce one-fifth of the nation's STEM bachelor's degrees. Moreover, the individual contributions of these institutions to STEM degree completions (measured as a proportion of all completions) are on par with non-MSIs. Perhaps even more impressive, students who graduate from MSIs do as well as, or even better than, those who attended non-MSIs in achieving upward income mobility, including in moving from the lowest to the highest income quintile by age 30.

Given the nation's urgent need for a well-trained, domestic STEM-capable workforce, and the strong equity-based argument for inclusion and diversity, MSIs are perhaps better poised than any sector within the US postsecondary education to solve the STEM workforce supply problem. As such, it is critical that policy-makers, education leaders, and STEM leaders alike more fully understand the needs of these institutions and their students—not only to better support current MSIs, but also to provide a welcoming landscape for the many MSIs that will continue to emerge in response to the nation's changing demographics. For example, in 2005 there were 245 Hispanic-serving institutions; in 2016 there were 492.

MSIs also play an important role in the two-year higher education sector. Two-year institutions are highly reflective of the nation's demographics and enroll a large portion of its students of color. Accordingly, in 2015, MSIs constituted almost 31% of all two-year institutions nationwide. Looked at another way, roughly 55% of all MSIs are community colleges. Still, these facts are often left out of the countless national conversations about STEM workforce, middle skills, multiple certificate programs, or the impact of free community college access. As such, there needs to be improved recognition and appreciation of the wide role that MSIs play in the nation's education system.

Despite their relative invisibility, MSIs have long served as important national resources for education, particularly STEM education. They will continue to be pillars of US higher education—but their importance and promise should no longer remain hidden. Indeed, MSIs are crucial resources for helping many students of color overcome historically entrenched obstacles to social and economic opportunity, and preparing MSI students for STEM careers can be a powerful catalyst for career success. Thus, in the interest of bolstering national achievements in STEM, enhancing the well-being of all US residents, and remaining competitive in a global economy, it is urgent that the nation determine the most effective practices and strategies to strengthen the quality of STEM education, research, and workforce preparation for MSI students.

The right stuff

But identifying what works at MSIs is only half the battle. To effectively expand and diversify the nation's domestic STEM workforce, there is a clear and urgent demand for large-scale investments in the nation's two- and four-year MSIs from key higher education and STEM workforce stakeholders—including federal and state governments, tribal nations (particularly in the case of tribal colleges and universities), and the philanthropic and private sectors. And to ensure that these investments pay off, several principals must be recognized and followed.

First, MSI leadership matters—a lot. It is critical that institutional leaders at both established and emerging MSIs—presidents, provosts, deans, and trustees—create a campus culture grounded in devotion to students, so that directly addressing their goals and needs (even when not fully aligned with the goals of faculty, alumni, or donors) becomes the anchor for all instruction, curricula, research, and social support systems on campus.

Second, going it alone may no longer work. It seems essential, at least in some instances, for MSIs to establish formal partnerships with local businesses and industries, and even with nearby non-MSIs, so students at less-resourced MSIs get access to high-quality research and work experiences that ensure that they enter the workforce with many of the same experiences and skills as their peers at research-intensive universities.

Third, the federal government needs to invest more money in MSIs. Although the current administration's focus on private-sector investments in Historically Black Colleges and Universities and other MSIs is laudable, it's not enough. More and stronger partnerships between MSIs and private business and industry are essential. But private investments by themselves won't come close to what is needed to create stronger research labs, update the curricula, and increase internships and other work-based learning opportunities at MSIs. Historical inequities in funding have left the MSIs with less capacity than many comprehensive universities. There are innovative and exciting initiatives on many MSI campuses, but too often still not at the level or frequency of non-MSIs. Given the projection for continued MSI growth, more money is needed, and the federal government will have to be the primary source of support. In addition to developing stronger support mechanisms to assist MSIs in competing for large grants from the National Science Foundation and the National Institutes of Health, more needs to be done to help these institutions successfully bid on the large, $100 million-plus federal contracts that the National Aeronautics and Space Administration, the Department of Energy, and the Department of Defense, among others, usually award to the major universities. Congress has an obligation to invest in MSIs—and should be incentivized to do so because the return on investments to the students, the MSI communities, and the national STEM workforce will be assets for the nation's future.

Finally, institutional accountability matters—a lot. But it needs to measure the right stuff and do so in the context of the unique challenges facing MSIs and their students. Specifically, federal and state educational agencies, state legislatures, and others should use accountability measures and metrics that take into consideration institutional missions, student populations, student needs, and institutional resource constraints at MSIs. Most standard accountability metrics fail to take these factors into consideration and are therefore inadequate measures of MSI performance. There is a need to explore additional attributes that characterize student success, such as social mobility and advancements in personal development and interpersonal skills, and to reexamine the methods used to measure success rates (for example, by expanding the period over which students are tracked, particularly for students who begin at two-year institutions).

The historical contributions, current value, and future potential of MSIs are a crucial part of the nation's educational story—as is their relative neglect as key pillars of the educational enterprise. That MSIs are so little recognized and understood is an object lesson in the difficulties of expanding minority representation in STEM fields. But if demography is destiny, then US economic prospects can no longer be separated from the educational prospects of its increasingly diverse student population. A substantial, and potentially uncomfortable, shift in thinking about the potential strategies to expand and diversify the nation's STEM workforce is essential for every American's future.

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FRAZIER BENYA

Treating Sexual Harassment as a Violation of Research Integrity

Sexual harassment harms researchers and the research enterprise in pervasive and pernicious ways that are not commonly understood or addressed.

Sexual harassment damages researchers, research products, and the research environment; it is a research integrity problem. It is therefore time for the research community to start treating sexual harassment as a violation of responsible research conduct. This means the community and its individual members must become more aware of how sexual harassment occurs in research settings, expand the range of behaviors that deserve censure, hold people accountable for the damage they are doing to researchers and research, and take actions to protect researchers and research from damage done by perpetrators of sexual harassment. Attending to sexual harassment in this way will take careful and creative thought and action by leaders and the research community. This article brings together the research on sexual harassment and on research integrity to inform and advance a conversation within the research community about effectively dealing with sexual harassment.

To explore how the research community could protect the integrity of research from sexual harassment, it is best to start by describing what sexual harassment looks like and how it harms people, then examine how sexual harassment affects the integrity of research and how the research community responds to and handles behavior that damages research integrity. This sets the stage for discussing how to bridge these two issues to take seriously the effect sexual harassment has on research. Valuable research and information to inform this conversation can be found in two recent National Academies of Sciences, Engineering, and Medicine reports, *Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine* and *Fostering Integrity in Research*.

Effects of sexual harassment on the integrity of research

Most people can identify two of the three types of sexual harassment: sexual coercion and unwanted sexual attention. Sexual coercion is the prototypical "sleep with me or you're fired" or "sleep with me if you want a promotion" or "sleep with me if you want to be first author" situation where career prospects are linked to sexual favors. Unwanted sexual attention is physical and verbal sexual advances that are unwelcome, unreciprocated, and unpleasant to the target of the advances. In some instances, these types of sexual harassment can include sexual assault, meaning that it can be both a civil rights violation and a crime. Yet these two varieties of sexual harassment are just the tip of the iceberg. (See Figure 1.)

By far the most common form of sexual harassment is gender harassment: "verbal and nonverbal behaviors that convey hostility, exclusion, or second-class status about members of one gender," as defined in the *Sexual Harassment of Women* report. This takes the form of demeaning jokes or comments about women, including comments that women do not belong in leadership positions, or are not smart enough to succeed in a scientific career. It can also include sabotaging women's work or careers, and denigrating them, often with crude language based on their gender. As a woman who is an assistant professor of engineering put it during an interview that was conducted as part of qualitative research for the National Academies sexual harassment study:

> Most of them are demeaning the woman, shutting her up in the workplace, demeaning her in front of other colleagues,

> telling her that she's not as capable as others are, or telling others that she's not [as] sincere as you people are ... I think more stress should be on that. It's not just, you know, touching or making sexual advances, but it's more of at the intellectual level. They try to mentally play those mind games, basically so that you wouldn't be able to perform physically.

This woman's comments were in response to a question about the impact of sexual harassment, and they reinforce what over 30 years of research shows: that sexual harassment is damaging and harmful even when it is not of the more blatant, threatening, and physical varieties that are at the top of the iceberg. In fact, research shows that frequent or severe gender harassment does the same professional and psychological damage as a single instance of sexual coercion. So when it comes to considering the effect sexual harassment has on the integrity of research, we should consider all three types of sexual harassment as causing damage, and we should be much more aware of the risk that sexist hostility and the crude behavior of gender harassment plays, especially in damaging the research enterprise.

Research on sexual harassment shows that it affects not only the mental and physical health of its targets, but their professional and education attainment as well. Increased harassment leads to decreased psychological health in the form of stress and anxiety. It can also result in eating disorders, fear, self-blame, lowered self-esteem, lower satisfaction with life in general, and physical symptoms such as headaches, exhaustion, and sleep disruption. Studies have even documented significant associations between sexual harassment and symptoms of depression and posttraumatic stress disorder (PTSD). According to one study, one in five sexually harassed women meet clinical criteria for major depressive disorder, and one in 10 meet criteria for PTSD. Additional research has revealed that exposure to gender harassment triggers levels of cardiovascular reactivity similar to what people experience in threat situations, which over the long term is linked with coronary heart disease and depressed immune system functioning.

Sexual harassment also damages work lives as people try to cope and escape abusive situations. When women are sexually harassed, their job satisfaction declines, they find their work more stressful, and their productivity and performance decline. They may withdraw from their work, taking more time off, using sick leave, being late to work or meetings, missing meetings, making excuses to get out of work, and neglecting tasks. Some will simply leave their institution to take positions in their field at another institution, but others leave their field altogether. Students may show similar signs of withdrawal by skipping or dropping classes, changing majors or advisers, or dropping out of school. And women of color, as well as sexual and gender minorities, will experience more harassment and more harm from the experience than white heterosexual women.

And yet, when a woman is subjected to sexual harassment, the harm may spread even further. Research shows that sexual harassment can impair team relationships and increase team conflict. And people of all genders who witness sexual harassment can themselves experience the same undermining of personal well-being that leads to work withdrawal. In hostile work environments characterized by sexual harassment, it turns out that everyone may suffer.

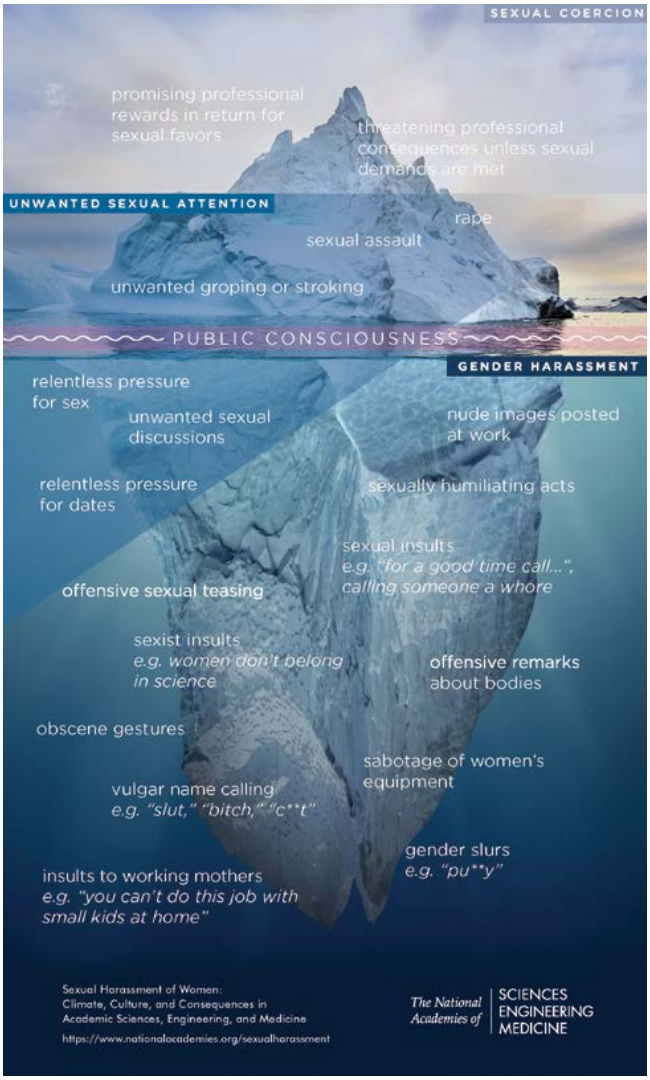

Figure 1

To illustrate how sexual harassment impacts the careers of women in science, engineering, and medicine in higher education, the committee that conducted the sexual harassment study commissioned RTI International to interview female faculty who had experienced such behavior. Their words provide powerful examples of how sexual harassment harms the research enterprise and damages women's careers and work. A number of women described how the experience of sexual harassment led them to miss out on leadership and research opportunities. One woman was instructed by her institution's human resources department to resign from an important committee position to avoid interaction with the perpetrator, who was the chair of the committee. Another dropped out of a major research project. Such experiences can also lead women to miss out on publishing opportunities when they either opt out of coauthoring because it would involve working with a perpetrator or when they are removed as an author as a form of retaliation. Similar dynamics play out at professional society meetings where women may protect themselves from hostile situations by choosing not to make presentations, or even attend.

> Yet the damage may not stop there, as the victims' professional reputations may suffer because colleagues often do not know why these women step away from career opportunities and disengage from work. As one nontenure-track faculty member in the geoscience reported:
> So, there's been a negative kind of chain of events where supervisors at the institution have seen that I dropped out of the research project and may not understand, because they were never told what happened. So, it seems ... I have been blacklisted in some ways and not invited to join other research projects and perhaps seen as a failure.
> Ultimately, the research enterprise is harmed as well, because promising careers are damaged, research findings are not shared with the community, and financial and other resources are wasted.

The idea that sexual harassment damages the integrity of research is not new. Two earlier reports by the National Academies, *Responsible Science* (1992) and *Fostering Integrity of Research* (2017), defined sexual harassment as "other misconduct"—one of three types of behavior (along with "detrimental research practices" and "research misconduct") that affects the integrity of research—and grouped it with misbehavior such as "other forms of harassment; misuse of funds; gross negligence by persons in their professional activities; vandalism, including tampering with research experiments or instrumentation; and violations of government research regulations such as those dealing with radioactive materials, recombinant DNA research, and the use of human and animal subjects." What has been frustrating for many—especially those who have been or are most likely to be harassed—is that the research community and research institutions have not taken seriously how damaging sexual harassment is to research, and so have not given it the same level of attention as other types of behavior that they readily recognize as damaging research integrity.

And yet, sexual harassment is not only damaging to research integrity because it is a form of "other misconduct," but also because it can result in behavior that falls under what the *Fostering Integrity* report terms "detrimental research practices"—the second of three types of behavior that damage research integrity. Detrimental research practices are described as including "denying authorship to those who deserve to be designated as authors," "neglectful or exploitative supervision in research," and "abusive or irresponsible publication practices by journal editors and peer reviewers." When a supervisor sexually harasses someone working under them or when sexual harassment in a research group leads to a scientist leaving the research group, this is exploitative supervision and a detrimental research practice. When sexual harassment leads to a scientist not getting authorship or other recognition for contributions to a project, this is denying authorship to those who deserve it and a detrimental research practice. When the promise of authorship or participation in research projects is conditioned on having sex with a supervisor or other colleague, this is a detrimental research practice. When refusal to accede to sexual coercion leads to denial of authorship or other credit for research contributions, this is a detrimental research practice. And when journal editors or peer reviewers use their authority to retaliate or sexually harass authors, this is a detrimental research practice.

The need for policy convergence

Over the past several decades, government agencies, research sponsors, and research institutions in the United States and many other countries have taken steps to prevent and address behavior that damages research integrity, but sexual harassment has often not been included. To date, these approaches have mostly taken one of two forms. First, regulatory frameworks have been introduced through legislation or policy that seek to a) ensure that researchers and research institutions follow important rules and procedures, b) that allegations of irresponsible behavior are investigated, and c) that corrective actions are taken when warranted. Second, agencies have introduced requirements that students, and in some cases others involved with research, receive training in the responsible conduct of research (RCR). Although the focus here is on the United States, it is important to remember that all research-performing countries are being challenged to address irresponsible research behavior.

The first formal efforts to address irresponsible research behavior emerged decades ago in reaction to revelations of wrongdoing, such as the human experiments undertaken by the Nazis, the Tuskegee syphilis study of the US Public Health Service, and widely publicized cases of laboratory animal abuse. Today, the policy and regulatory structures aimed at protecting human research participants and laboratory animals in the United States involve oversight and monitoring at the federal and institutional levels. Locally, Institutional Review Boards and Institutional Animal Care and Use Committees are responsible for reviewing research plans and proposals, and for ensuring institutional compliance with laws, regulations, and policies. Requirements are complex, with education and training playing an important role in protecting both human participants and laboratory animals.

In the 1980s, in response to a series of data fabrication and falsification allegations against prominent researchers, and questions about the adequacy of institutional responses to those allegations, new policies and regulations were introduced to address research misconduct. Before that time, research institutions were solely responsible for preventing research misconduct and addressing allegations. In 2000, the Office of Science and Technology Policy adopted a policy for federally funded research that defined "research misconduct" as data fabrication, data falsification, and plagiarism, and specified procedures to be followed by research institutions and agencies in response to research misconduct allegations. These policies require research institutions to notify the funding agency when cases move from the inquiry stage into a formal investigation and to notify the agency of the results of the subsequent investigation. As with policies protecting human and animal research subjects, both the National Science Foundation (NSF) and the National Institutes of Health (NIH) have introduced RCR training requirements for grant-supported and other researchers.

The next phase in the evolution of policies and processes to protect and improve research integrity is to integrate actions to deal with sexual harassment into the regulatory frameworks and training on responsible conduct of research. This will take collaboration and coordination among those who are responsible for harassment issues at research institutions (such as Title IX officers, human resource officers, ombuds officers, and general counsel offices) and those who are responsible for the protection of research integrity (such as research compliance officers, research integrity officers, responsible conduct of research educators, and Institutional Review Board members).

Expanding RCR training to include problems of sexual harassment is the most obvious first step in this evolutionary process. This would require that RCR instructors and educators develop the skills to speak and teach about sexual harassment in the research setting. It would also mean that behavioral expectations would have to be clearly established and articulated, much as they are for RCR training in mentoring and research supervision.

The more challenging and complex need is to bring sexual harassment under the umbrella of research integrity regulatory frameworks so that damage to the research enterprise is formally recognized as a consequence of harassment. This integration will require a number of important changes or additions to the current system for identifying and addressing violations of research integrity, including:

- Sexual harassment investigations should be coordinated, and results shared, across federal agencies.
- "Trusted persons," who in the research context are there to provide information and guidance before someone proceeds with a formal investigation, need to be prepared to handle individuals coming forward with sexual harassment experiences, and institutions need to ensure that they can remain trusted sources rather than mandatory reporters who will have to inform the institution about the incident against the victim's wishes.
- Institutions must be held responsible if they show a disregard for, or inability or unwillingness to implement and follow, the regulatory requirements related to sexual harassment and its effect on research integrity regulations, and for substantial or recurrent failures to comply with the regulatory requirements covering sexual harassment and research integrity.
- Penalties for sexual harassment violations of research integrity should reflect the need to protect the research process and researchers, and they should include a variety of measures depending on the severity of the behavior, such as removing perpetrators from grants; suspending or terminating grants; prohibiting perpetrators from serving on advisory committees or peer review committees, or as consultants; requiring supervision for perpetrators; and debarment of perpetrators from eligibility for federal funds for grants and contracts.
- Research and publication of results should be halted when active investigations are ongoing and the severity and type of the behavior warrants it.
- Measures should be put in place to recognize and prevent retaliation in research settings, but especially those forms of retaliation that further damage research integrity.

The National Science Foundation has recently announced that academic institutions must report when NSF-funded researchers are found to be responsible for sexual harassment, or when administrative action is taken against NSF-funded researchers. This policy is already leading to conversations between university Title IX offices and research compliance and integrity offices. The hope is that it will also result in penalties that protect researchers and the research from damage caused by sexual harassment. What is needed now is an effort to make such policies consistent across federal funding agencies so that the nation does not end up with a patchwork of rules, and so that federal funding agencies stand together against sexual harassment in research.

The pervasiveness of sexual harassment across society has only recently come into focus. That sexual harassment is a problem in the research enterprise is thus unsurprising, but the threat that it creates for research integrity needs to be more widely recognized and addressed. We certainly do not yet have all the answers for how to protect the research community from the damage caused by sexual harassment—damage to people, to careers, to institutions, to teams and projects, and to science itself—but the problem demands, and is finally beginning to receive, the nation's utmost attention.

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ASHLEY BEAR AND DAVID SKORTON

The World Needs Students with Interdisciplinary Education

When students can understand and make connections across a diverse array of knowledge and skills, they embark on a path to more rewarding lives and employment opportunities. Higher education can and must do a better job of leading the way out of disciplinary silos.

Students at Syracuse University are developing a deep understanding of neurobiology through the process of writing haiku. At DePauw University, students are learning about biochemistry by creating sculptures based on protein-folding research. Harvard Medical School students are improving their communication, visual literacy, critical thinking, and empathy through art observation. Olin College of Engineering students are learning about alloys in the context of the life of the American patriot Paul Revere, best known for his "midnight ride," but also a skilled silversmith. LaGuardia Community College students are writing essays on mathematics as it relates to the origin of Western thought.

These educational approaches reflect a growing sentiment that standard curricula have become too segregated or siloed along disciplinary lines, and that in an increasingly complicated world, students are having difficulty understanding the connections between diverse forms of knowledge and inquiry. This movement in higher education goes beyond the general education curriculum found at almost every institution of higher learning in the United States, in which students take several disconnected courses in different disciplines outside their major. In this integrative model, the knowledge, modes of inquiry, and pedagogies from multiple disciplines are brought together within the context of single courses or entire programs of study. In such a model, professors help students make the connections between these disciplines in an effort to enrich and improve learning. This model is both new and old. It is new in that society is witnessing a recent surge of interest and enthusiasm for more holistic and integrative approaches in higher education, and it is old in that it is rooted in the longstanding tradition of a liberal education that dates as far back as Socrates and Aristotle. Today it goes by many names, such as "STEAM" (with an "A" for "arts" added to the standard STEM acronym for science, technology, engineering, and mathematics), "convergence," "transdisciplinary," or even "SciArt."

Over the past two years, we had the opportunity to examine this trend in higher education in the context of a National Academies consensus report, *Branches from the Same Tree: The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education*, that explored how approaches to teaching and learning that integrate across disciplines might better prepare students for work, life, and citizenship. While working on this report, we spoke with many faculty and administrators who voiced concern that college graduates today are leaving higher education having taken an array of seemingly disconnected courses, with those courses outside their declared major seeming irrelevant to their interests and unrelated to the world beyond campus. We heard that many students are asking themselves: If I am a science or engineering major, why do I need to know about ethics, history, writing, and design? Shouldn't I just focus on the classes that will prepare me to get a job after graduation and to succeed at that job? What we learned is that a holistic education that integrates the arts, humanities, sciences, and engineering will make students more attractive candidates for employers and more successful in their future career—or, more likely, careers. The challenge for higher education will be to teach students in a way that helps them understand the connections between diverse forms of human knowledge so they can appreciate, for example, the ethical dimensions of writing software that collects people's personal data without their knowledge or the importance of intuitive and aesthetic design in the engineering of a profitable smartphone.

Indeed, some of the learning outcomes associated with integrative approaches—including improved written and oral communication skills, teamwork skills, ethical decision making, critical thinking, and the ability to apply knowledge in real-world settings—are the very same outcomes that employers and university administrators alike agree that all students should possess upon graduation. Recent surveys reveal that employers see talent as more than deep technical expertise or familiarity with a particular technology. Employers are also looking for well-rounded individuals with a holistic education who can comprehend and solve complex problems that transcend disciplines. An online survey conducted by Hart Research Associates found that the majority of employers say that both field-specific knowledge and a broad range of other kinds of knowledge and skills are important for recent college graduates to achieve long-term career success. Very few employers indicated that acquiring the knowledge and skills needed primarily for a specific field or position is the best path to long-term success. Employers reported that when hiring, they place the greatest value on demonstrated proficiency in skills and knowledge that cut across all college majors. The skills they rated most important include the ability to communicate clearly, both in writing and orally, teamwork, ethical decision making, critical thinking, and the ability to apply knowledge in complex, multidimensional, and multidisciplinary settings. According to employers, this combination of cross-cutting skills is more important to an individual's success at a company than the major she or he pursued while in college.

A study by Burning Glass, a job market analysis company, reported similar results. Its textual analysis of 25 million job postings aimed at understanding "the essential or baseline skills that employers are demanding across a wide range of jobs" revealed that oral communication, writing, customer service, organizational skills, and problem solving were among the most prized skills across a wide range of occupation and career types. The study also categorized the importance of what were termed "baseline skills" and "technical skills" by occupation groups. The results of this analysis speak to the importance of both job-specific technical and baseline skills and the relative importance of these skills by occupation type. Predictably, jobs categorized as being within the domains of information technology, engineering, health care, the physical and life sciences, mathematics, and manufacturing require more technical skills than categories such as sales, marketing, or human resources. But even among the highly technical fields, a quarter to a third of the required skills deemed essential by employers fall within the baseline skills. The results suggest that higher education should equip *all* students with the baseline skills needed for success in a wide range of occupations.

This conclusion is all the more important because, as shown by US Census Bureau data, students who major in the standard liberal arts disciplines—in STEM as well as arts, humanities, and social sciences—often end up in professions that are not directly aligned with their major, just as specific occupations attract students with multiple kinds of academic preparation. These data raise questions about how well a college or university curriculum focused on a specific, disciplinary major will serve students after graduation.

Moreover, graduates should be prepared not only to take a job that does not directly relate to their college major but also to change jobs and careers often throughout their working years, particularly in the years just after graduation. According to a 2016 Bureau of Labor Statistics report, younger workers (ages 25-34 years) stay in a single job for an average of 4.2 years. These data suggest that graduates will be well served by skills and competencies that are transferrable from one job to another, as well as by the ability to be adaptable, lifelong learners who can pick up the new knowledge they may need for success and fulfillment in each new job.

Why does all this matter? Because employers also report that many recent college graduates have not achieved the kinds of learning outcomes that they view as important. Employers want to hire people who can apply knowledge and skills in real-world settings, think critically, and communicate clearly and effectively in both writing and speaking. And in these areas, fewer than 30% of employers think that students are well prepared. More than 80% of employers feel that colleges and universities need to do a better job helping graduates gain cross-cutting skills and knowledge.

Yet institutions of higher education largely agree on the importance of this same set of competencies. Although higher education in the United States is an incredibly diverse enterprise, comprising a vast array of different types of institutions that serve a variety of student goals and educational purposes, research has demonstrated that there is broad agreement across this diverse landscape of institutions on the importance of student learning outcomes. A survey released in 2016 found that nearly all members of the Association of American Colleges and Universities—which constitute a majority of the nation's four-year colleges and universities—have adopted a common set of learning outcomes for all their undergraduate students. Shared learning outcomes include writing and oral communication skills, critical thinking and analytical reasoning skills, ethical reasoning skills, knowledge of global world cultures, and "integration of learning across disciplines." The survey also found that general education is growing as a priority and that administrators are more likely than they were in 2008 to report an emphasis on the integration of knowledge, skills, and applications. This integrative turn of higher education signals a shift to intentional and purposeful learning across knowledge, skills, and personal and social responsibility.

Given the high level of employer dissatisfaction with the core competencies of college graduates, the movement toward a more integrative approach in higher education couldn't be more timely—for students, for communities, for employers, and for the nation. Today the value proposition of US higher education has become less apparent to a large percentage of the population. Many people are struggling to understand the return on investment in a college education as they weigh rising costs that far outpace inflation, even as more and more employers are requiring a postsecondary degree for jobs that did not previously require one. Indeed, surveys have demonstrated that most US residents today view higher education as a path to a good job. As many people have come to see higher education more as a private commodity than a public good, states have invested less money in higher education and have increasingly linked resources to demonstrated employability of graduates. Disinvestment has created pressure at many institutions to promote skills and training that are considered more likely to lead to immediate job placement, which has led to a perceived need for greater specialization. This trend has in turn reinforced the view of higher education as largely a path for workforce preparation best pursued through a narrowing curriculum, contrary to the historical mission of institutions of higher learning, which embraced a more expansive view of education as helping to prepare students for life and productive citizenship.

Yet, as we have discussed, the notion that disciplinary specialization and technical depth are the only important prerequisites for employment turns out to be false. Institutions of higher education and employers turn out to be generally aligned in their view of the kinds of cross-cutting skills and knowledge students should possess upon graduation. Such student learning outcomes can be achieved when professors help students make the connections between disciplines and appreciate that, in the words of Albert Einstein, "all religions, arts, and sciences are branches from the same tree."

But to realize a vision of higher education that emphasizes the importance of a holistic, integrative education, institutions must first ensure that effective teaching practices are a priority for faculty and administrators. This may mean reexamining incentive structures such as tenure and promotion criteria, which, as everyone knows, too often emphasize and reward publication and grant funding over teaching practices, integrative or otherwise. But now society is also beginning to understand that the lack of emphasis on integrative teaching practices may actually serve students poorly in the job market. Although the evidence in support of an integrative approach is promising, it is certainly the case that more research is needed to understand the impact of individual courses and programs on students' lives. Thus, along with developing stronger incentives for quality teaching, universities also need to evaluate the impact of different teaching practices in higher education.

The good news is that we see higher education moving in this direction. We catalogued over 200 programs and courses across the broad spectrum of US higher education—community colleges, research universities, technical colleges, and liberal arts colleges—that are taking innovative new approaches that better integrate knowledge and pedagogies from the arts, humanities, sciences, engineering, and medicine. These courses and programs (which are surely a subset of the total number of integrative efforts in higher education) exist despite the many institutional barriers to integration. Their existence demonstrates that it is possible to bridge between entrenched disciplinary silos. Many of these courses and programs are framed around the global and local challenges that many students are passionate about addressing: climate change, obesity, poverty, to name a few. If this movement toward greater integration in higher education persists, perhaps in the future students will no longer major in a specific science, engineering, art, or humanities discipline, but rather will focus their studies on addressing the many real-world challenges they are likely to encounter in the context of their careers, lives, and civic engagement.

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