stakeholder collaboration, dissemination, high-fidelity implementation, and evaluation.

As part of national efforts to build an inclusive and equitable training environment, we must reframe career and professional development as a core part of STEM training, as integral as understanding basic genetics principles is to becoming a geneticist. Building national capacity for testing and disseminating educational innovations will accelerate advancement of graduate education practices. As STEM PhD career trajectories continue to evolve, our ability to adapt educational practices will be essential for continuing to attract talented prospective students to PhD training, and ultimately for the health of the scientific enterprise.

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As a group of current and recent STEM graduate students, we applaud Alan Leshner and Layne Scherer's argument for systemic changes that are essential to improving graduate education. Many of their points deeply resonate with our perspectives, especially the lack of support for students and preparation for jobs outside academia. As this article ironically notes, "Over 20 studies and reports on graduate (STEM) education have come to that same conclusion," while research institutions continue to struggle to create sustained change.

Increasing numbers of PhDs are pursuing nonacademic careers rather than tenure-track faculty positions, but we believe that framing these changes as an effort to "modernize" is problematic. It allows the established academic community to avoid responsibility for and reflection on the institutionalized flaws in graduate student training. Graduate STEM education systems have always had an obligation to be ethical, empathetic, and all-around mindful of the needs and goals of the students, contrary to the implications that this is a contemporary challenge.

Indeed, "real change requires a systems approach," as their article notes, but all levels of the academic ecosystem are not equal in their power and influence. Students have a responsibility to pursue interdisciplinary training and professional development, and faculty have a responsibility to be inclusive and supportive resources for their students. But we believe that the critical role of university administrations and deans is being dangerously overlooked. Leshner and Scherer acknowledge the fact that systematic change is inherently difficult in decentralized systems, which further highlights the importance of holding institutional leadership to a higher standard, since they reflect a small number of individuals with immense local power. The recommendations in the recent National Academies report on which the authors based much of their article should be prioritized and integrated into top-down university hiring requirements, strategic planning, and budget allocations in order to lead by example and shape campus culture to be conducive to change-making at the faculty, staff, and student levels.

Furthermore, a call for changes in funding criteria from state and federal agencies is not sufficient to produce more than superficial results. Successful systematic change will also require putting the spotlight on institutional leaders, challenging them to think creatively and holding them accountable on their promises to prioritize graduate student success.

It is especially important that all levels of leadership within academic institutions support the bottom-up grassroots efforts of graduate students. In the absence of institutional support, these student-led efforts are providing hands-on experience, community building, and public outreach that fill the gap in professional development opportunities. For example, the National Science Policy Network is comprised of early-career scientists and engineers across the United States who are pursuing focused training and professional development opportunities that align with science policy and advocacy career goals. Unsurprisingly, the majority of these efforts operate on shoestring budgets or even on the sheer willpower of student volunteers. In response to the National Academies report, we hope that more university faculty and administrators will step up as allies and advocates who can facilitate the prosperity of graduate student- and postdoc-led endeavors.

Ultimately, early-career researchers who don't feel welcome or supported in academia because of their extracurricular efforts aren't going to stay around to eventually become tenured committee members and advocate for this vision of reformed STEM graduate education. Instead, they will leave, and myopic attitudes toward graduate education will continue to proliferate within the walls of academia. However, the pursuit of healthier and more equitable academic environments; higher-quality of teaching, advising, and mentoring; and expanded support for more interdisciplinary curriculum and research has the potential to benefit not only individual students but also the broader standing of science in society.

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ENGINEERING EDUCATION REINVENTED

Richard K. Miller begins his article, "Lessons From the Olin College Experiment" (*Issues*, Winter 2019), by stating that "higher education is notoriously hard to change." This statement is accurate, as this desired change presents challenges, but it is also

PHILLIP K. SMITH III, *Lucid Stead: Focused Views - View 6*, 2013-2019; Archival pigment print, 47 x 8.75 x 6 inches

Lucid Stead: Focused Views

Phillip K. Smith III took this series of photographs in 2013 prior to closing the *Lucid Stead* installation. The photographs are detailed and cropped views of the homestead shack, drawing attention to the relationship between the weather-worn wood, reflection, and the environment.

The day after Smith took these photographs, he decommissioned the work by returning the cabin to its original state with one exception: He did not reattach the original wood siding he had removed, but rather kept it catalogued in his studio. These woods slats would become the originators of the *Lucid Stead Elements* sculptures, one of which is also featured in the exhibition at the National Academy of Sciences.

an opportunity. Based on the successful 20-year history of engineering education innovation at Olin College, Miller, who is president of the college, offers five lessons learned during the creation from scratch of the educational experience there, from working with an initial class of 30 "Olin Partners," to a campus-wide commitment to continual innovation, to the challenges experienced once the inertia of success sets in. Indeed, Olin College has rightly enjoyed tremendous success during a short period, creating an identity as a leader and innovator in undergraduate engineering education.

How do these ideas for education innovation and lessons from Olin College's first 20 years translate to an institution such as the College of Engineering at the University of Illinois at Urbana-Champaign, which is an order of magnitude larger than Olin College and steeped in rich history with an already established strong identity and legacy? Can new pedagogical models take root and flourish at a large research-focused university and college of engineering such as ours? The iFoundry in our College of Engineering was created in 2007 to challenge our traditions and to pilot such models. In the 12 years since its inception, we have learned and confirmed many of the lessons described by Miller. Collaborations between faculty from Illinois Engineering and Olin College have helped solidify the bedrock principle of what is now our Academy for Excellence in Engineering Education (AE3), which offers an additional lesson learned.

That lesson is: communities of practice support faculty-driven innovation. Over the past six years, through our Strategic Instructional Innovations Program (SIIP), 28 teams comprising over 120 faculty have

PHILLIP K. SMITH III, *Lucid Stead: Focused Views - View 4,* 2013-2019; Archival pigment print, 44 x 30.5 inches

led real change in the classroom, including integrating design thinking across curricula, developing a robust online framework for learning and assessment, and enhancing the communication skills of engineering students. A group of Education Innovation Fellows (EIFs), themselves engineering faculty, shepherd the teams in their endeavors. Importantly, these EIFs serve as the connective tissue between different SIIP teams and academic departments, catalyzing communities of practice within the college that support and sustain education innovation. This combination of tight-knit communities working on specific innovations and bridging interactions between teams allows the ideas that work to rapidly spread throughout the college.

Another key component to our success has been taking an engineering approach to education innovation: developing and prototyping educational ideas, measuring the real impact on our students, and then learning whether to pivot or persevere. Our engineering faculty have taken the lead in creating and scaling education innovations by teaching in the same way that we do research—with collaboration, creativity, excitement, measurement, perseverance, and continual improvement. We have found that the broader engineering faculty are more apt to buy in and adopt successful ideas when the innovations are driven by their peers and based on scholarship. By taking this approach, ideas can incubate in more manageable settings before scaling and spreading across curricula to positively impact thousands of Illinois Engineering students each year.

Though "higher education has been notoriously hard to change," change must happen in order for the nation to prepare the future engineers to adapt to the rapidly changing cycles of innovation and to improve the human condition by tackling the grand challenges facing our increasingly connected world. Maintaining disciplinary depth, expanding cross-departmental interdisciplinary breadth, project- and problem-based learning, integrating design-thinking and an entrepreneurial mind-set, and expanding communication skills are all important elements in pursuit of the change. The lessons from the Olin College experiment have brought us many steps closer to realizing this change.

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