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Nurturing Deeper Ways of Knowing in Science

Efforts to diversify representation in science and engineering require initiatives that increase diversity of thought as well.

In an ironic twist of fate, I was recruited in 2021 by the University of California Los Angeles as tenure-track faculty through an engineering mentorship initiative. The UCLA Samueli School of Engineering and Applied Sciences was searching for faculty with a record not only of academic excellence—in my case, in ultrafast and quantum photonics—but also of commitment to mentorship of underrepresented student groups. The school's laudable aspiration was to fill one of the many voids faced by marginalized and underprivileged students at various steps in their undergraduate programs. The mentorship program was a "talent promotion and retention" policy of sorts, a means to help close the graduation rate gap across identity groups and, perhaps incidentally, to "diversify" the emerging workforce and fix what is often called the "leaky pipeline" of eager and qualified students who, for one reason or another, abandon engineering degrees.

I say ironic because over the last decade, I have been by turns supportive, skeptical, and critical of policies and conversations focused on diversity, equity, and inclusion, or DEI. I've been exposed to and led some of these discussions and initiatives as a student, scientist, and academic in universities, research institutions, and government agencies in Europe and North America. DEI has shifted social norms and public awareness around representation and equity in the fields of science, technology, engineering, and medicine (STEM). But discussions have grown stagnant, and I've come to believe that the thinking around DEI has been too limited. In focusing on representation based on identity group alone, the DEI movement has missed an opportunity to address a broader failing of STEM education that significantly undermines its ability to pursue justice: STEM education produces narrow, uncritical thinkers, regardless of identity group. In order to truly "open up" the STEM pipeline to a broader group of people, the field must embrace deeper diversification of thought and ways of knowing.

Adopting weak notions of diversity promotes the individualization of problems and solutions that ought to be collective. It can leave systems of inequality and injustice in place—and even make them more effective. Even as it has focused on representation, an underlying motivation of DEI efforts has been to include people with different life experiences and different ways of thinking, to make science better serve and reflect society. What has been overlooked is that there are many ways of generating knowledge, or of coming to know something. Today's technoscientific world is shaped by an epistemic hierarchy: knowledge generated through the scientific method is privileged, while methods such as traditional or native wisdom, philosophical or spiritual reasoning, and symbolic or mythical interpretation have not been included. This system, however flawed, has been established and reinforced by dominant cultural values.

And although science is directly and fundamentally connected to the epistemic question of how we know what we know and what it means to know something, in university STEM classrooms and laboratories, there's no serious consideration of epistemology or critical theory or the myriad ways of making sense of the world. As a result, STEM students and professionals are ill-equipped to rigorously consider, for instance, the societal impacts of their inventions and discoveries.

Can there be true diversity in STEM without acknowledging the deep diversity of knowing? I believe the answer to this question is no. Pursuing justice and targeting prejudice in STEM is inextricably bound to embracing critical thinking as a core principle—going well beyond representation based on identity group alone.

How DEI got here, briefly

Individuals and organizations alike seem to struggle with the very definition and implementation of diversity and inclusion. The academic community gets caught up in categorizable, data-driven evidence (or a lack thereof), and launches into activating single agenda items intended to "move the needle." The issue at hand is extremely complex because, as the Black feminist philosopher and writer Audre Lorde said, "We do not live single-issue lives."

Many surveys over the decades document the evolution of the stark differences in career outcomes among various identity groups in STEM fields. The earliest studies focused on statistical performance based on gender binaries alone, and then began to expand to intersect race, sexual preference, and physical (dis)ability. Today, a number of hypotheses are marshaled to explain institutionalized discriminatory policies. These include implicit biases—for example, discrimination based on expectations of gender performance—or shortage of labor supply, among others. This collective perception of the problem has led to a diversity of institutional(ized) actions, including targeted hiring, mentorship programs, and implicit bias training.

Many of us working directly or adjacently in DEI argue that the standard menu of interventions may provide some value but shows debatable results in absolute terms. For instance, while the number of women faculty in STEM fields has gradually increased over recent decades, the percentage of women of color faculty in STEM has declined. Critics have questioned interventionist policies and flagged their dubious success as lacking intersectionality. This is the idea that when the intersectionality of all identified groups—race, ethnicity, gender, ability, sexuality, nationality, and so on—are not only considered but also recognized, all are more likely to thrive professionally because social injustice can be identified and, in some cases, quantified. This framework, either together with or independent of policies put in place to patch the leaky pipeline, can shine light onto the specific barriers of selection, promotion, and retention and attempt to remediate them. But efforts to apply intersectionality analysis to, say, research design, remain uncommon.

While it's important to lean into these dynamical complexities, the fact remains: the pipe is unrealistically linear, and simply too epistemologically narrow to admit broader thinking and broader thinkers. Adding to this, the 2023 Supreme Court decision *Students for Fair Admissions v. Harvard College*, which effectively ended race-conscious admissions policies, combined with some policymakers' contention that DEI initiatives are "extremist," suggests that new strategies are needed to bring more of society into STEM. We should look for these new strategies by examining root causes and the reproduction of injustice and inequality.

Deepening ways of knowing in STEM education

In higher education, analyses of injustice and inequality reside quite comfortably, although not without pushback and academic debate, in the so-called soft sciences. Meanwhile, the hard sciences are tasked with providing marketable products like technology and a skilled workforce. Today's starkly delineated, separable subject matters and siloed disciplines in higher education produce STEM students and professionals who are well-equipped for task- or technology-oriented performance, but ill-equipped to understand and evaluate the interconnectedness of their work in society. This is further exacerbated by naïve, reductionist popular narratives of technological advancement and subsequent positive social impacts.

I joined UCLA partly because I was excited by the possibility of forming a coalition to help address this very evident deficiency in STEM. I dreamed of a future where the engineering community thinks in radically different ways and celebrates broad thinking and diverse epistemologies. By the end of 2021, as a newly minted faculty in engineering and physical sciences, with mentorship and financial support from the UCLA Center for Advancement of Teaching, I was part of a wider two-year process to develop new curricula that became Humanities-Informed STEM, or HI-STEM.

The first step of the curricula was meant to be exclusively pedagogical. A series of courses would aim to equip STEM undergraduate and graduate students with the critical frameworks that typically reside in the humanities, social sciences, and arts. The hope was that the students would then be better equipped to disrupt the design, implementation, and deployment of technology, scientific epistemology and methodologies, and even science and technology policy itself. Achieving this goal required collaborating with scholars across the arts and humanities, medicine, science and engineering, social sciences, and education.

During this same 2021–2022 academic year, while developing HI-STEM, I launched the first instructional activity through a Fiat Lux seminar series entitled Upending the Hard Sciences. (Fiat Lux is a UCLA-wide program that allows for such types of general education seminars to be offered for credit.) As a cornerstone of UCLA's undergraduate curriculum, the program brought together students and faculty to engage in meaningful discussions on a range of topics. Upending the Hard Sciences consisted of six consecutive panel discussions with scholars and faculty from the sciences and humanities. Each of the seminars explored intersecting strains of critical analysis that challenged hierarchies in STEM, including queer and Black geographies, gender essentialism, colonial sexuality, queer ecology and ecofeminism, nonessentiality, Black and Latinx futurism, Indigenous temporalities, and queer time.

The series was very well received. We generated transcriptions and published them as review articles, and produced videos of the recorded panels. By spring 2023, our collaborative had completed the HI-STEM curriculum's first iteration and published it as a blueprint white paper to facilitate wider adoption.

In the 2023 winter quarter, the first HI-STEM pilot was offered as a four-credit course to 10 undergraduate and graduate students from the UCLA Samueli School of Engineering and Applied Sciences. Classroom activities started with foundational critical analysis, including Black and Indigenous pedagogies, queered science and technology studies, and feminist theories. For each framework, students were given required and suggested reading materials to supplement class lectures and discussions.

In-classroom engagement was anchored in active discussion. For example, disability studies helped us steer discussions of accessibility and assistive technologies beyond the usual examples of prosthetics and robotics into new territory, such as technological adaptations to climate and ecological changes. Native feminism introduced case studies examining traditional ecological knowledge and community structures that the group then used to reconsider the extraction of fossil fuels and the use of quantum technologies in blood and genetic ancestry tests. Critical queer theory introduced students to medical and biological surveillance infrastructures, their linkage to predictive algorithms, and the potential for harm.

The class was structured to help students comprehend and apply the theories—and be unafraid to get in over their heads. After the first of two weekly classes, students were tasked with writing an "application card," where they had to take the pedagogies and theories reviewed in class to real-world situations and suggest how these could be relevant to STEM. This form of assessment required students to demonstrate an understanding of the frameworks and identify additional contexts in which they could be applied.

At the end of the week's second class, students were asked to submit a short, written reflection that identified any open or remaining questions, summarizing the "muddiest point." With this simple assignment, we leaped to an uncommon conclusion in STEM instruction—an unclear, confusing, frustrating, or even angering conclusion, with more questions stemming from a nuanced, educated, and layered apprehension of the problem at hand.

Toward the end of the course, each student was tasked with developing an original case study on a relevant or contemporary STEM-related challenge or opportunity and applying these frameworks to meaningfully engage with dominant STEM paradigms or practices. The coursework ended by asking students to devise strategies to integrate aspects of their case study into local or global community engagement initiatives.

Forming a community around critical analysis

I had never taken a course like this, so I was excited and apprehensive as I began teaching the class. Any self-doubt I had was consistently vanquished by students' open dialogue around a multiplicity of interpretations, value statements, triumphs, and discomforts. Toward the end of the quarter, they led discussions and wrote pieces on emerging themes such as queering the CHIPS and Science Act (an exercise of reevaluating and reassessing motifs in technology development), exploring the right to be forgotten, the nuances of digital personhood, and how we might reconsider the assumptions inherent in the material sciences using the lens of Indigenous and ancestral knowledge.

This communal practice in critical analysis—a fundamentally overlooked part of developing our STEM workforce—allowed the students and me to collectively dream of new futures. The classroom lent itself to a gradual erosion of well-established STEM truths to make space for other truths to grow. Together, we studied and analyzed unethically gathered data and how it can lead to biased outcomes that perpetuate and exacerbate a long tradition of technologies created by and for the people who dominate STEM jobs, often at the expense of other groups. We could then look cross-subject—from data to petroleum production—at some of the *extractionist logic* embedded in science, engineering, and technology industries.

For example, the role of semiconductors in shaping economics, geopolitics, and workforce development has been well explored, but a student in the class looked more closely at the underlying logic of the CHIPS and Science Act's promises to "uplift" marginalized groups or to "clean up" the environment. Using feminist-critical frameworks, the student offered an alternative to the act that saw the creation and usage of semiconductor technology as a way to truly offer a more just and sustainable approach to the technology. This alternative would work, she argued, by "creating electronics that give back to the land and communities from which it readily extracts resources and labor."

In doing this critical analysis, students' exploration was heavily influenced by the book *Vexy Thing: On*

Gender and Liberation, in which race, gender, and law scholar Imani Perry outlines how patriarchy operates as an active force. Sovereign powers define personhood by seizing and redistributing property through legal frameworks, she writes. In this context, the violent legacies of colonialism and slavery were an important part of the legal and philosophical definitions of personhood—determining who possesses rights, power, and ownership of property (and crucially, who does not). When Perry's analyses were used in the classroom, one of our students used them as the basis for exploring how these ideas might challenge an emergent form of digital personhood, linking corporate control to digital sovereignty, and reclaiming the internet's potential as a *commons*, that is, a power-aware, communally focused philosophy of identity data.

Naturally, this course could be taught through the lens of many other thinkers (such as Ivan Illich or Sheila Jasanoff), frameworks (such as Marxist criticism or sociolinguistics), and multimodal (or nonwritten) methodologies, from embodied critiques to audiovisual and art-based research. My intent is for HI-STEM to be a playground for us to continue to explore these alternatives as our times and collective consciousness evolve. It is the process of engaging in critical thinking and scientific literacy that anchors the successful outcome of this approach.

One of the most meaningful realizations I had as the instructor was witnessing a community form in the classroom: As a group, we discovered that we had similar interests and unease with how problems and disciplines had been presented to us throughout our academic lives and beyond. I found out that I am not as alone as I'd thought in seeing a disconnect between our various disciplines and what it means to be a scientist today.

In their course evaluations, the students expressed a strong appreciation for the interdisciplinary nature of the course, highlighting the importance of integrating humanities into STEM education, describing it as crucial for fostering critical thinking and understanding multiple modes of analysis. One student noted: "I've taken many humanities classes before but I really appreciated how this course attempted to provide a broad overview of main epistemologies from a variety of humanities disciplines, offering a sort of 'sampler platter' to get us interested in all these different areas and, hopefully, to convince people to dig a little deeper and read more about these concepts or take more classes in them."

Following the success of the pilot, HI-STEM is being offered as a UCLA Engineering course starting in winter 2025, with an enrollment of 50. It is expected to grow to an annual enrollment of 150 over the next few years. Going forward, HI-STEM will also add a research component, to produce scholarly work that further bolsters the legitimacy of this training and its critical place in today's world.

Disrupting and even *queering*—that is, using the tools of critical theory to challenge norms and hierarchies—categories in STEM by mapping linkages to political and economic systems, humanities, and social sciences has a unique capacity to educate the future STEM workforce to critically examine their role and responsibility in shaping society. Whether tackling climate change mitigation technologies, bringing in new ways of thinking about energy, or critiquing urban mapping and surveillance technologies, I hope that students will carry these analyses into the field—as well as into other STEM classes.

Creating a context for diverse ways of knowing to thrive

So where do we go from here? I suggest thinking carefully about how to create the conditions and the context in which diverse ways of knowing can thrive. Recruiting more people from marginalized backgrounds into STEM and instituting changes that support them is important. But this must also be accompanied by processes that question, disrupt, and possibly reconstruct the systems that force us to seek such diversity to begin with. That is to say, no policy changes to fix the leaky pipeline will prove sufficient without changing the structure of the system itself.

I don't think we can imagine new ways of doing science, or generating knowledge, for any meaningful positive social change until we are willing to get muddy—until we abandon false divisions between how we do science and engineering and how society engages with these creations. This may require difficult and painful explorations to uncover how deeply epistemic hierarchies are buried in our individual and collective unconscious. It also requires envisioning how to undo these structures to experience and practice science anew. I'm constantly reminded of Audre Lorde's adage: "The master's tools will never dismantle the master's house."

HI-STEM was never meant to provide solutions. It is a means to muddy technoscientific processes and ways of thinking so engrained that it is impossible to imagine anything differently. I recognize that muddying is destined to fail. However, how exactly we fail holds significance. It is within these instances of failure that profound unlearning can occur, offering insight into the complexity of our shared challenges. Let's get muddy, let's fail generatively, so perhaps we can imagine a better future.

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