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Building Diversity, Equity, and Inclusion into an Engineering Course

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ABSTRACT

Engineering faculty have heard the call to incorporate diversity, equity, and inclusion (DEI) into their classrooms, but many have asked the question: What can I do to advance DEI in my courses? This commentary provides one answer. We summarize our process to engineer DEI into an undergraduate fluid mechanics course following a process that included (1) participation in formal programs, (2) a systematic review of course materials, and (3) a weekly series of conversations that examined DEI in the context of engineering education from academic, social, and personal perspectives. The formal programs deepened our awareness; the systematic review identified improvements in the syllabus, nomenclature, and videos; but most importantly the conversations illuminated how the same technical material can be associated with vastly different cultural perspectives—a key point from the theory of Culturally Relevant Pedagogy. We call for engineering faculty to seek opportunities to learn more of these perspectives, and then to reflect on how to improve their courses accordingly.

Key words: diversity, higher education, classroom

CALL TO ACTION

2020 was the year when the term *systemic racism* went mainstream, appearing, for example, in the flagship journal *Science* (Thorp 2020). Each of us have been asked to consider how our individual attitudes, behaviors, and choices might privilege some while disadvantaging others, or conversely, how they might instead support the spirit of diversity, equity, and inclusion (DEI).

If you teach engineering, you may have asked yourself what—if anything—you can do to support DEI in your classes, your research group, your department, your campus, and in our collective engineering culture. Here we focus on our classrooms to ask the question: How can we engineer DEI into an engineering course? Many engineering faculty struggle to answer this question. We suspect there may be several reasons for this struggle, as we discuss below. The simple objective of this commentary is to share the process we followed in a particular engineering course.

Let us begin with a physical analogy for motivation. Multiple lines of evidence tell us that engineering education in the United States has not achieved its full potential, where achieving our full potential is analogous to reaching a global energy minimum (Figure 1). Instead, we are stuck in a local minimum, trapped by a potential barrier. We suggest this potential barrier results, at least in part, from generations of engineering professors imitating their predecessors. To be sure, there are many positive aspects about engineering culture. But other aspects of engineering culture serve to divert brilliant students and colleagues into other careers. It takes work to overcome an energy barrier; we call for that work to be done by engineering faculty.

What aspects of engineering culture may be exclusionary? There are many. Seron et al. (2018) identified meritocracy and individualism as central to engineering culture, which is problematic,

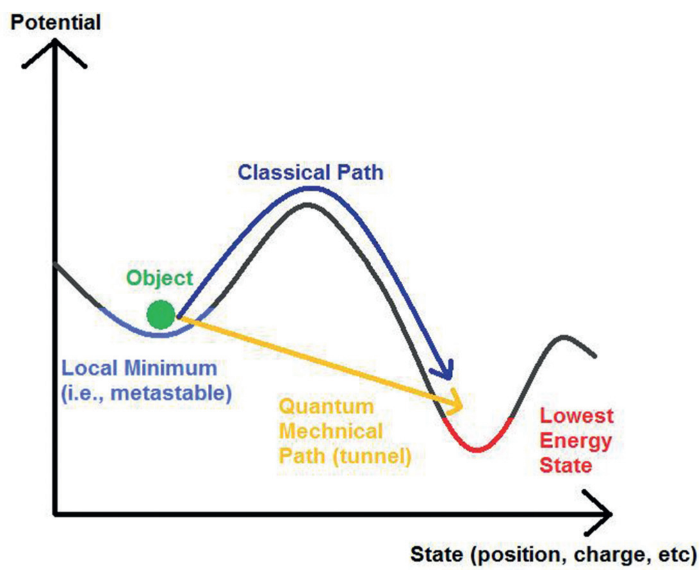

Figure 1. Metaphor for engineering education as an object in a local energy minimum (Cranberry 2008), such that work is required to achieve the lowest energy state. The authors are not aware of anything analogous to quantum tunneling. Improving engineering education will require work.

because so-called meritocracy often adopts an unnecessarily narrow view of merit, and because individualism is contrary to the emphasis many students place on community. Another source of exclusion is the ideology of depoliticization, defined as “the belief that ‘social’ issues can and should be bracketed from the more ‘technical’ aspects of engineering” (Cech 2013). This ideology of depoliticization comprises the notions of abstraction, generality, and objectivity (Ressler 2011). Most engineering faculty have been trained to think about abstract ideas like free body diagrams and control volumes, rather than particular structures or rivers. Most engineering faculty prefer one general equation that works for all materials in all applications, rather than a place-based approach that considers the unique aspects of different places and peoples. And most engineering faculty strive to remove themselves from the analysis, on the premise that anyone doing the same experiment would reach the same conclusions. These notions are deeply embedded into engineering faculty culture, and while anyone can think abstractly, generally, and objectively, these notions constitute a narrow emphasis that is not the only way to approach learning, in the same way that not all students are auditory learners (Felder and Brent 2016). While the technical content is independent of the cultural context, engineering faculty must recognize that technical content always comes wrapped in cultural context. This is a key point, because adopting a narrow emphasis leads to privileging some students while excluding others. If faculty want to make engineering classes welcoming to more people, they must find alternative ways to frame the technical material.

To help us envision an alternative that is inclusive, not exclusive, let us consider the theoretical framework of Culturally Relevant Pedagogy (Ladson-Billings 1995). Our premise is that multicultural societies like the United States should have multicultural engineering schools. Given that multicultural premise, the theory of Culturally Relevant Pedagogy argues that learning requires three interlocking elements—stuff, self, and society: First, the course must provide an opportunity for students to study the technical material (stuff). Second, the course must provide an opportunity for students to understand culture, their own and others, which Ladson-Billings called *cultural competence* (self). And third, the course must provide an opportunity for students to consider the sociopolitical context of the technical material (society). The trouble is that many engineering faculty focus entirely on stuff without leaving much space for self or society. How can we retain and enhance the technical material while adding, indeed welcoming, differing points of view?

To provide a few examples of differing points of view, let us share a little about ourselves, and suggest why it matters. CR is an Indigenous scholar (Diné and Mescalero Apache) in political science studying how the cultural framework of higher education, particularly in science and engineering, interacts with the cultural background of students. DCM is an Irish American scholar in civil engineering studying groundwater hydrology. We met through our mutual participation in the interdisciplinary program Environmental Stewardship of Indigenous Lands. We recognize that sharing personal information along these lines is highly unorthodox in engineering scholarship, but providing this background is required to appreciate the following examples.

For example, both of us have relatives who worked in the oil and gas industry in Texas. But while CR's grandfather realized his employment in oil and gas was antithetical to his identity as an Indigenous person, DCM's uncle derived enormous satisfaction and a sense of purpose from his employment in oil and gas. Same industry. Conflicting paradigms.

As a second example, consider the contrasting photographs in Figure 2. CR associates fluid mechanics with the photograph in Figure 2(a), which shows Sahnish tribal chairman George Gillette in tears after being forced to sign the 1948 Garrison Dam agreement that would scatter his people. This historical photograph documents the forceful relinquishment of land (Wells 2007), with Gillette's response frozen in time to document the devastation that this would cause his people. This image illustrates how culture, identity, and sociopolitical context matter. At least until collaborating with CR, DCM had also associated fluid mechanics with dams, but with a limited focus on the technical material along the lines of Figure 2(b), which shows water discharging from Hoover Dam on the Colorado River. Both figures certainly relate to fluid mechanics, but while Figure 2(a) is personal, Figure 2(b) is impersonal; while Figure 2(a) associates fluid mechanics with the trauma endured by colonized peoples, Figure 2(b) associates fluid mechanics with environmentally-friendly electrical power. These worldviews are fundamentally different. Appreciating this difference is a prerequisite to successfully broadening participation in engineering.

Figure 2. Contrasting images of fluid mechanics. (a) Tribal chairman George Gillette weeps after being forced to sign the 1948 Garrison Dam agreement that would disperse his people (https://www.indianz.com/news/2003/002677.asp). (b) Water discharging from Hoover Dam on the Colorado River (https://www.usbr.gov/lc/hooverdam/faqs/tunlfaqs.html).

Here is a third example, regarding the definition of fluid mechanics itself. Engineering faculty with traditional engineering training probably would define fluid mechanics as the branch of physics concerning properties, motions, and forces of liquids and gases. In the framework of Culturally Relevant Pedagogy, this definition lies squarely within the realm of technical material. But an Indigenous, Black, Indigenous/Black, or other marginalized student might define fluid mechanics as follows: Fluid mechanics takes land from Indigenous people and places a dam on it. This definition encompasses broader concepts such as giving land stewardship back to Indigenous people (Thompson 2020). Fluid is water. Water is life. Water is found on Indigenous land. Discussing this in a fluid mechanics class is essential in the presence of Indigenous students, because slapping a land and slavery acknowledgement on a syllabus without having this discussion is dishonest.

OUR PATHWAY

Our pathway focused on fluid mechanics, which is a required 3rd year course for civil engineering majors at the University of Colorado Denver (CU Denver). Most civil, environmental, petroleum, chemical, mechanical, aerospace, and biomedical engineering students take an equivalent course. In response to the COVID-19 pandemic, CU Denver provided graduate student fellowships to assist faculty with reformatting their courses for remote instruction, providing 20 hours/week of support for 12 weeks in summer 2020. During that process, we worked as a student-faculty team to rebuild the course to optimize learning for all students, mindfully including women; Indigenous, Black, and Latinx students; those who identify as lesbian, gay, bisexual, transgender, or queer (LGBTQ); and anyone else who has been marginalized in traditional engineering education. We approached this rebuild with a three-part strategy that included (1) formal programs offered by CU Denver, (2) a systematic review of course materials, and (3) a weekly series of conversations that examined DEI in the context of engineering education from academic, social, and personal perspectives. Let us discuss each of these in turn.

The formal programs were the Hybrid Flexible Teaching Academy, an asynchronous online course with synchronous office hours with a more experienced online instructor, and Diversify Your Syllabi, a program offered through CU Denver's Auraria Library. Participation in the Hybrid Flexible Teaching Academy provided a broad perspective on effective remote teaching, which was helpful, considering that the sudden transition to remote teaching in March 2020, at the onset of the global COVID-19 pandemic, had been conducted as an emergency response. Participation in Diversify Your Syllabi assisted in incorporating more inclusive content by suggesting inclusive STEM topics to improve the classroom's content for students of color. We replaced some (although not all) personal nomenclature

Table 1. Selected revisions to syllabus text.

Fall 2019	Fall 2020
I reserve the right to return homework for re-write and re-submit if it is (1) illegible, or (2) does not comply with the following standards:	To clarify the presentation, accelerate the grading, and develop attention to detail, homework must comply with the following specifications:
Late homework will be penalized by 10% per class (except by 15% from A→B).	Life happens, so late homework is accepted—no questions asked—with a penalty of one letter grade per class.

with technical nomenclature, changing “Bernoulli” to “Energy Equation” and “Buckingham Π” to “Dimensional Analysis.” This change replaces jargon with more descriptive wording and counters the incorrect notion that fluid mechanics is exclusively by and for white men. Second, we softened the tone to replace authority with support (Table 1), which is intended to help students envision a more supportive relationship with their professor, while still expecting students to meet reasonable standards. And third, we added a brief land acknowledgment, “Auraria Campus is located on the original homeland of the Arapahoe, Cheyenne, and Ute Nations.” This acknowledgment represents a symbolic first step in a longer journey to place the course in a cultural context to acknowledge that this land has been taken.

The systematic review of course materials included the assigned videos, the in-class examples, and the online test proctoring. During this review, we asked two questions: First, do these course materials marginalize anyone? Second, do these course materials represent a missed opportunity to engage anyone?

The most time-consuming aspect of the systematic review of course materials was the search for alternative videos. From Fall 2005 through Fall 2019, this course had required six videos of about 30 minutes each from the National Committee for Fluid Mechanics Films, an educational series designed to support technical education during the Cold War, and sponsored by the U.S. National Science Foundation in the 1960s-70s. If one looks beyond the archaic cinematography and the extremely homogeneous demographics of the presenting faculty (*i.e.*, white men), these videos continue to convey fluid mechanics beautifully. But a preponderance of anecdotal student feedback contradicts the premise of that last sentence. Students do not always look beyond archaic cinematography—which is a problem for all students—or overlook homogeneous demographics—which again suggests that fluid mechanics is exclusively by and for white men. This led to a search for alternative videos, starting with suggestions from fluid mechanics students at CU Denver over the years. We then considered fluid mechanics-related videos from the online resources Beals Science, Cal Poly Pomona, Crash Course Engineering, FY Fluid Dynamics, Physics Girl, Practical Engineering, and SmarterEveryDay. Any of these online resources offer dynamic modern cinematography and, taken as a group, they offer a reasonable balance of gender. But with the exception of Crash Course Engineering, there does not yet appear to be much racial diversity among the available fluid mechanics educational videos.

The systematic review considered the in-class examples, none of which were designed to marginalize, but many of which were considered to be missed opportunities to engage. Why? Because they were too abstract, which is a missed opportunity to engage with students who see the world more concretely. To partially address this concern, we added an open-channel flow example from Machu Picchu, an Inca city in the Andes (South America) whose construction began in the 1400s (Wright et al. 1997). This example reinforces the countercultural idea that the engineering discipline of fluid mechanics does not belong exclusively to Europeans or those with European ancestry. But beyond this example, our review of in-class examples identified a need for future work. We searched for an online database of fluid mechanics examples including a variety of cultural perspectives, but finding none, we found that 20 hours/week for 12 weeks was insufficient time to transform a course's worth of in-class examples (above and beyond the other tasks summarized above).

The systematic review also highlighted troubling concerns with proctoring software for online exams using facial recognition technology (Swauger 2020). Briefly, this class of software is more likely to incorrectly block marginalized students from taking online exams, which presents an unequal playing field. Moreover, proctoring software creates an adversarial relationship between students and faculty that is detrimental to learning, the polar opposite of a welcoming classroom culture that promotes learning.

The third element of our three-part strategy was weekly meetings. At first, these meetings focused on the logistics of transferring the course materials from 100% in-person to 100% remote: Zoom meetings, Canvas pages, and the like. But after a few weeks, these meetings evolved into a series of conversations that examined DEI in the context of engineering education from academic, social, and personal perspectives. Unlike the checklist- and schedule-driven discussion of transfer logistics, these conversations were exploratory and open-ended, and consequently, they elicited statements of our own identities, contrasting paradigms for the oil and gas industry, and differing perspectives (Figure 2). After working together for a summer, we gained perspective through formal training, made changes in fluid mechanics at CU Denver (syllabus, videos, and proctoring) and identified future work (in-class examples). These changes should have a positive impact on this particular class. But more importantly, by engaging with each other over a shared project, we brought to light some of the differences in perception that, we think, encapsulate the real challenge of bringing DEI into engineering education (Figure 2). If we want to teach better, engineering faculty need to listen when possible, engage our students in a culturally appropriate way, and honestly deal with history and the current marginalization of students. There needs to be a shared agenda. Until faculty do these things, there will be no marked change in the demographics of engineering.

YOUR PATHWAY

How does one engineer DEI into an engineering course? We contend this is the right question; we do not claim it is trivial. The Colorado Equity Toolkit (2019), a free online resource for teachers at all levels, starts with self-inquiry, which implies that each of paths will be different. To elaborate on this important notion of self-inquiry, Brookfield (2017, Chapter 4) articulates four lenses of critical reflection, through (1) students' eyes, (2) colleagues' perceptions, (3) personal experience, and (4) theory. Here we argue that a helpful theoretical framework is Culturally Relevant Pedagogy (Ladson-Billings 1995), but we make no claim that is the only relevant theory. Culturally Relevant Pedagogy asks engineering faculty to consider a much broader context for their teaching, beyond the technical material, to include cultural and sociopolitical context—including many other nontrivial concepts such as intersectionality, positionality, lived experience, and the concept community (as opposed to individuality). But you do not need to become an expert in every aspect of this broader context. Your path will be different because we all have different lived experience. What brings us together is that we are all trying to undo harm and bring students from all backgrounds into engineering. If you want to improve engineering education, you need to get started. Certainly, formal training provides helpful perspective, and a systematic review of course materials provides tangible improvements—not only for marginalized students, but for all students. But even more important than formal training or a systematic review, we feel, is for engineering faculty like you to avail yourself of opportunities to gain perspectives that differ from your own, and then to conduct yourself, your classes, and your in-class examples in light of those perspectives.

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