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Torquing Engineering: Historical and Contemporary Challenges to the Technical Core via Internationalization

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Some of my earliest struggles to relate my technical coursework to my wider dreams and interests occurred while I was an undergraduate student at Michigan Tech. Demarcation quickly emerged as a path of least resistance. Fueled by a passion for computers that ran back to my grade school years, I found a measure of comfort and satisfaction immersing myself in the decontextualized technical nuances of electrical and computer engineering, from learning how to wire up circuits and code programmable logic chips to exploring new worlds of integrated circuit design using various CAD and simulation tools. At the same time, I discovered a growing passion for social and environmental issues, which I nurtured by taking a cluster of elective courses in the area of Science, Technology, and Society, and getting involved with our university's Student Pugwash chapter. These parallel paths worked well enough, but were never completely satisfying. As I started to question everything from the role of computers in society to the place of corporations in a democratic state, I found the onus was largely on me to figure out the significance of such issues in relation to my technical studies, not to mention some of the main career pathways for computer engineers – which I looked upon with growing skepticism.

Like many others in this situation, my desire to reconcile these tensions carried well beyond my undergraduate education, ultimately leading me to pursue graduate degrees in Science and Technology Studies (STS) at Virginia Tech. And as a faculty member in engineering at Purdue University, I am now firmly on the other side of the looking glass dividing student from teacher. Yet as I have worked to develop and deliver learning experiences for students that introduce them to the sociocultural dimensions of engineering education and practice, I find myself grappling with some of the same problems of curricular demarcation that I first encountered as an undergraduate student. Part of the irony of this situation centers on what happened during the intervening two decades, which included introduction of ABET's Engineering Criteria 2000 (EC2000) accreditation framework.[1] In principle, this reform opened up new space for transformative change in engineering education, including enhanced integration of the field's technical core with other kinds of global and professional competencies and outcomes. Yet for a variety of reasons, at most schools the core has remained largely impervious to change.

Such trends have not gone unnoticed. Cech and Sherick, for example, have written persuasively about how a stubbornly entrenched "ideology of depoliticization" has powerfully inflected the form and content of engineering education, namely by demarcating the technical dimensions of engineering from any associated political, social, or cultural considerations.[2] This ideological boundary-work projects a sanitized and idealized image of engineering as ultimately divorceable from anything deemed subjective, sociocultural, or humanistic – that is, anything "non-technical." The idea of "social/technical dualism" has also been used by Faulkner and others to describe how the technical aspects of engineering are often viewed as both superior to and separable from social dimensions.[3] Further worth noting is Cech and Sherick's discussion of how engineering education perpetuates such schisms by reinforcing historically dominant – yet increasingly antiquated – images of the profession's epistemological, ethical, and ontological foundations. This hegemonic reproduction impedes efforts to transform engineering faculty, courses, curricula, and culture in ways that might breach the boundaries between the field's technical core and the actual sociotechnical realities of engineering practice.

These challenges are particularly evident in ongoing efforts to "internationalize" engineering education, where preparing engineers for the global dimensions of their work has raised questions about how to cultivate global competency in the midst of already crowded technical curricula, not to mention rising demand for many other kinds of professional capabilities deemed important for future engineers. A growing body of engineering studies scholarship has also shown that the technical core of engineering appears even less stable and coherent when viewed in cross-national comparative perspective, with partially distinct epistemological, ontological, and cultural characteristics powerfully inflecting engineering practice in different locales.[4] Nonetheless, recent decades have seen only modest growth in the number of courses and programs focused on global engineering and allied topics.[5] Leading change agents have responded to this trend by trying to diversify the global learning portfolio, including by scaling up research and work abroad placements, advocating for global service learning programs, and promoting on-campus global learning and community building.

The primary goal of this paper is to interrogate how the technical core of engineering education has resisted change for more than five decades, particularly given growing internationalization efforts and pressures. To keep the account manageable, the paper is organized around three episodes, one historical and two largely based on the experiences of individuals, including the author. This focus on personal perspectives aims to highlight the "micropolitics" that come with attempts to change deeply entrenched systems, while also helping to reveal what Bowker and Star call the "torque" that change agents often encounter when their identities and/or actions work against dominant modes of classification or categorization. Before delving into these lived realities, it is worth briefly reviewing how early discussions about internationalizing engineering education emerged in tandem with a hardening of the field's technical core.

Episode 1: Internationalization and Accreditation in the mid-1950s

As documented by Jesiek and Beddoes, some of the first discussions about preparing American engineers to work abroad surfaced after World War II, with diplomatic and international development concerns acting as primary drivers.[6] During this period, a handful of commentators started discussing specific attributes and experiences that could enable these new career paths, including some supporting roles that schools of engineering might play. Paul McKee, President of Pacific Power and Light Company, took one of the more conservative positions of the time:

> [I]f one is to practice engineering abroad, he should first of all be given the finest and highest type of engineering education available. … [F]rom an educational standpoint the best possible basic training for work abroad is a sound and thorough knowledge of reading, writing and mathematics, plus a thorough groundwork in basic engineering principles. A good working knowledge of the English language and of the history of our country and at least a general understanding of the history of the world is also essential.[7]

McKee's commentary also referenced many other kinds of attributes and experiences important for success working abroad, but made it clear that these were to be developed after graduation.

Others argued that undergraduate engineering education should play a more prominent role. For instance, Cornell Professor of Civil Engineering N. A. Christensen described growing need for both “top quality engineering scientists” and “engineering statesmen,” arguing that the latter should be “trained to have the breadth of social knowledge and technical excellence to transfer American know-how in civil engineering to underdeveloped countries.”[8] Christensen clearly took the position that some of this know-how should be developed at the undergraduate level, adding that “[t]he 20 per cent of humanistic activities so widely accepted is only a start toward what is needed.” S. S. Steinberg, Dean of Engineering at the University of Maryland, took a similar position. Discussing how American engineers might support Truman’s “Point Four” program – which aimed to provide technical assistance to developing countries – he explained: “[I]t may be that supplying this technical knowledge to other lands will require training in our engineering colleges fully as broad in the technical fields as now, but probably with a broader basis in the humanistic-social field, aiming toward living and working in foreign fields.”[9]

In addition to implying that students preparing for international experiences should receive a typical kind of technical education, Steinberg’s remarks foreshadowed the Grinter Report’s subsequent calls to codify the amount of attention paid to humanities and social studies topics in engineering degree programs. While calling on reformers to “strengthen and integrate work in the humanistic and social sciences into engineering programs,” the report elsewhere suggested a segmented approach whereby “about one fifth of the curriculum should be devoted to humanistic and social studies.”[10] As documented by Stephan, the ECPD accreditation criteria were updated accordingly in 1955 to require at least one half-year (or about one eighth of a typical four-year curriculum) of “humanistic-social studies” for engineering graduates.[11] This curricular model was largely unchanged for many decades, until the move to ABET EC2000 in the 1990s.

As Christensen had acknowledged, the traditional rule-of-thumb regarding “humanistic studies” in engineering was likely inadequate for the aspiring “engineering statesmen.” Yet the new ECPD accreditation criteria not only explicitly codified an even lower bound on the humanities and social science courses for engineering student, but did so in relation to all other requirements (e.g., mathematics, basic sciences, engineering sciences, engineering analysis and design, etc.). In other words, it was hypothetically possible to increase the proportion of humanistic-social studies courses in a given engineering program, but doing so was a zero-sum game that would likely displace other requirements long viewed as much closer to the heart of engineering education and practice. As summarized by Downey, the 1950s and 1960s were a time when engineering educators were mainly focused on “re-building the technical core of engineering curricula around the engineering sciences.”[12] Another kind of strategy might involve integration of topics across courses, but this seemed an even more remote possibility given prevailing attitudes of the time. In fact, Stephens notes that another period ASEE report found that “many engineering schools were treating non-technical subjects in a cursory and even hostile fashion.”[11]

Episode 2: Living Resistance Beyond the Technical

As an environmental engineering student at Penn State in the late 1970s, Jim Mihelcic was eager to add an international dimension to his university experience. Yet like many before him, he faced considerable resistance. As Mihelcic recounts: “I remember as an undergraduate how I wanted to take a foreign language and ‘ABET’ would not allow me within the confines of my engineering degree. I also remember how I wanted to do a 'study abroad' in St. Petersburg and there was no room in the curriculum for the courses or funds to assist the semester overseas."[13] Fortunately, such negative experiences did not quash Jim's interest in international education, which later manifested in his efforts to create new courses and degree programs at Michigan Tech. Yet he again faced skepticism and resistance, only now from his fellow faculty: "[t]ime after time, at my previous institution, in department meetings and the hallway, traditional colleagues suggested to me that by incorporating a human dimension or sustainability into a technical problem, or internationalizing our curriculum, the rigor of the solution was somewhat diminished."[13] He adds that seeking approval for such changes from recalcitrant curriculum committees as one of the "most frustrating aspects of engineering education."[13]

Especially notable in the preceding passage is Mihelcic's inability to internationalize his own education, either through an on-campus or off-campus experience, and in considerable part due to policies which helped insulate the engineering curriculum from any perceived threats to its technical core. Over a span of more than five decades, a growing body of evidence has shown that these types of constraints have seriously impeded the internationalization of engineering education. This trend is often described in aggregate terms as authors lament over a persistent underrepresentation of engineering students in study abroad, or note the relatively small number of engineering schools that are taking international education seriously. Yet Jim's story comes from a 2011 volume that dared go where others had not through "personal narratives" authored by sixteen engineers, non-engineers, and "hybrids" (those with mixed backgrounds) who have championed international education for engineering students – often at considerable risk to their reputations and careers. These accounts capture the considerable passion of the contributors, while offering rare glimpses of trial and tribulation as these change agents encounter people and systems impeding their efforts, many hostile to what are perceived as incursions on the technical core of engineering.

Nonetheless, even the contributors to this volume frequently adopt a rather defensive and self-conscious tone in describing their efforts, as though concerns about technical rigor are always lurking about, waiting to pounce. Discussing the history of a flagship program he helped launch, for example, Mihelcic explains: "I had a stated goal of the Peace Corps Master's International program to educate engineers who are not only grounded in the fundamentals of engineering, but they are also educated and trained in the many critical, non-technical skills that are required of today's engineer."[13] Parkinson, describing his efforts to establish a list of desirable competencies for global engineers, concluded that "U.S. engineers therefore needed to add additional value, beyond technical skills, to remain competitive in the worldwide marketplace."[14] And McKnight, describing his involvement with developing international programs as Georgia Tech, similarly noted that "[t]he relationship between a technological university and industry had come full circle on the strength of a student's performance that demonstrated not just technical skill, but the ability to adapt thoroughly to another culture, to a considerable extent by going through the window of its language and culture."[15] Is it possible that these individuals have been challenged so frequently that they instinctively ground their claims in the technical core and then building outward? For some, this may indeed be a way of reducing the amount of "torque" they experience when challenged to work with others who view the technical core as sacrosanct.

Segue: Torque

In *Sorting Things Out: Classification and Its Consequences*, Bowker and Star introduce the concept of "torque" in discussing the "interaction of classification systems and biography."[16] The term was originally used by these authors to describe how individuals who do not fit within hegemonic categories often live their experience on the boundaries through a disruptive sense of bending and twisting at the hands of more powerful actors, policies, and institutional structures. For example, Bowker and Star use the extreme example of the apartheid system in South Africa to describe how the lives of individuals and families who crossed the color barrier (or were perceived to do so, such as through physical markers like skin tone) were frequently distorted and thrown asunder when they encountered prevailing systems of racial classification.

Here I liberally and somewhat apologetically borrow the concept of torque to describe what often happens when individual actors resist or challenge prevailing systems of classification, e.g., the implicit and explicit boundaries between the technical core of engineering and everything else. And while some kinds of torque are profoundly more disruptive than others – perhaps even incomparably so – I find the term helpful in capturing the burden of distortion, unease, and even isolation so frequently born by individuals who dare challenge that which is dominant. Indeed, it is a feeling I have experienced repeatedly as a faculty member who is living on the boundaries.

Episode 3: Torque Despite Demarcation

As a new tenure-track faculty member at Purdue, I arrived with the idea that I would eventually like to develop and support courses and programs on global engineering and related topics, in part because I had done considerable teaching and research in this area as a graduate student and postdoctoral scholar. In fact, in my application and interview I presented global engineering as one of my major areas of scholarly interest, and this seemed to be well received by my future colleagues. Nonetheless, I landed in a department that was mainly focused on teaching first-year engineering and graduate-level courses, which meant that there was no ready pathway for me to create and offer an undergraduate elective course on global engineering. Further, there was relatively little room, much less incentive, for me to bring global themes into the highly prescribed and coordinated curricula for the introductory engineering courses I was teaching. Indeed, as a junior faculty member I was repeatedly reminded that I should reduce risk to my tenure case by focusing my energy on research rather than teaching or developing courses.

Nonetheless, one of our Associate Deans became more aware of my expertise and interests, and inquired about whether I wanted to help create and deliver an undergraduate elective course called "Discovering Engineering." One of his main inspirations for such a course was a series of interactions with students outside of engineering, including future K-12 teachers, who had surprisingly little knowledge about who engineers were and what they did. A new course could help familiarize them with engineering, while also exposing engineering students to the historical development, global dimensions, and contemporary status of engineering education and practice.

After discussing the opportunity with my department head, I informed the Associate Dean that I could provide resources and advice, but was not yet in a position to get more deeply involved. Interestingly, some of his first efforts to develop the course were supported by a undergraduate research assistant from Liberal Arts, who culled through the materials I sent and then led development of everything from a course schedule and assignments to lecture slides and notes. Later supported by a graduate teaching assistant who was also one of his advisees, the Associate Dean first offered the class in Spring 2012 as a temporary course, and with a main focus on "examining the progression of engineering throughout history and its impact on society." The major course topics included: history of engineering, engineering and society, diversity in engineering, global engineering, and ethics and sustainability. Only three students ultimately completed this first offering, foreshadowing recruitment problems to come.

As 2012 progressed, my tenure and promotion case was looking stronger, global engineering had become one of my focal research areas, and I had also taken on an additional administrative role as an Associate Director of the College's Global Engineering Program. Part of that role involved expanding "on-campus" learning opportunities for our engineering students, including new courses, workshops, training sessions, etc. Further, our College of Engineering was feeling growing pressure from the university's new core curriculum initiative, especially given widespread reluctance among the engineering faculty to opening up their courses to students from outside of engineering – itself representing a potent example of the technical core of engineering being insulated from perceived outside incursions. In fact, only one elective program in the College wanted to have its courses recognized as part of the core curriculum, which meant the Associate Dean was eager get a class like Discovering Engineering on the books for all students at Purdue. Given such factors, my department head and I agreed that the time was right to take over the effort, and the Associate Dean replied in kind by partially funding one of my graduate students to help design and teach the next iteration of the course.

We planned to offer the course again in Fall 2012 under a temporary course number, but with a new title ("Engineering in Context") and more focused on the kinds of global and cross-cultural themes that had become central scholarly interests for me. Yet despite some intense last minute promotional efforts, we ended up with only three students enrolled, and during the first week of course they all withdrew due to scheduling conflicts or discomfort with the shrinking class size. We also started to recognize other reasons why the course was not attracting more students, including uncertainty about how it fit into already overloaded plans of study. This issue was exacerbated by the course's temporary number, lack of reputation and history, and unclear status as either a technical elective or general elective. Here it should also be noted that some engineering departments and advisors at Purdue are relatively open about what courses can count as technical electives, while others are much more restrictive. Still another constraint centered on our attempt at a "2+1" model for the course, which required students to enroll in 2 credits for the course itself and another 1 credit of service learning or undergraduate research, which we imagined as a way to relate the course content to other kinds of learning. But this proved problematic since it meant the course did not fit into the mold of a typical 3-credit elective.

After cancellation of the course in Fall 2012, pursuing a permanent course number seemed like a good – and perhaps overdue – strategy to help establish the course's legitimacy. Nonetheless, this proved much more difficult than initially expected, as it meant moving a course proposal through at least four levels of approval, namely the undergraduate curriculum committee and then the faculty in the author's home department, where the course number was located, followed by the College's curriculum committee and then the university registrar. First attempts to advance the proposal failed after a more senior faculty member expectedly took responsibility for seeking informal input on the course from the College's curriculum committee, only to return with a suggestion that we needed a longer track record of success with a temporary course prior to permanent approval. Faculty in the department also made many other recommendations for possible improvements and refinements to the course proposal. Needless to say, little forward progress was made that semester. I felt like I was facing an intractable chicken-and-egg problem, since without a permanent number we could not attract enough students for a viable course. I also felt that my experience teaching a similar course at my previous institution served as ample evidence of its potential for success, but this fact had largely been ignored or downplayed.

Encouraged by the department head, I rebounded by bringing a revised course proposal before our faculty in January of 2013. The meeting minutes indicate that no fewer than fourteen new issues were discussed, many of them focused on how to market the course to higher-level decision-makers in the College who were suspected of being skeptical of anything new of different. First worth noting was a recommendation to emphasize the course's "global" themes, ultimately leading to a new title, "Engineering in Global Context." Other feedback centered squarely on the course's seemingly ambiguous position vis-à-vis the field's technical core. For example, the engineering prefix used for the course number was questioned, with an engineering education designator proposed as more appropriate. A sample assignment in the proposal was also deemed too controversial because it asked students to write a memo describing their vision for reforming engineering education, with particular emphasis on diversity themes. Further, I was asked to add much more detail, such as by clearly mapping all learning outcomes throughout the document and giving brief descriptions of every assignment rather than just titles.

While the tone of that discussion is probably best described as "constructively critical," I was feeling defensive given my sense that the proposal was being scrutinized beyond reason. In fact, the meeting minutes explicitly noted that expectations for the document were higher than usual since the proposed course was different than "standard" engineering courses, and since it was not entirely clear whether students in the class would "do engineering" as opposed to studying "what engineers do." This latter point of feedback is especially fascinating for how it attempts to neatly bound engineering practice from so-called "studies of" engineering practice. Indeed, this is particularly ironic given that most engineering faculty at my institution have never practiced engineering professionally, and it is likely that many of the technical topics they teach will be neither remembered nor used by students after they graduate and enter the workforce.

After recovering from another round of considerable annoyance, I undertook further revisions and placed the proposal back in front of our faculty in February of 2013. I remained committed to keeping the course's engineering prefix in place, which I saw as a very important symbolic challenge to traditionally narrow definitions of what counts as engineering. However, I did address many other issues that were raised, including by writing up assignment descriptions, mapping learning outcomes, and incorporating a more conventional sample assignment. I also developed a longer statement of justification that spoke in depth about my previous experience teaching a similar course, including the fact that other versions of the class had been offered more than 50 times to more than 3,000 students at two other schools. The course proposal passed the department unanimously. And despite so many concerns raised about getting subsequent approvals for the course, later in the semester it was accepted by the College's curriculum committee without issue, and shortly thereafter approved by the registrar.

Conclusion

Like others who have blazed similar paths, my dogged efforts to get permanent approval for a non-traditional elective course in engineering – which represented an important part of ongoing efforts to "internationalize" our College by increasing access to on-campus global learning experiences – was accompanied by considerable torque. My record of accomplishment as a teacher, faculty member, administrator, and researcher suggested I had more than adequate qualifications to develop and teach this type of course, yet through a belabored and antagonistic process I experienced multiple instances of doubt, disillusionment, and identity questioning. Regularly crossing the social/technical divide and wishing to develop a course that defied boundaries, the process repeatedly reminded me that I was working against a powerful, normative system that is strongly biased toward an ideal image of engineering that can ultimately be distilled down to an unadulterated essence of technical purity. Yet it might have been a compliment had my course been deemed an impure hybrid! Instead, I have increasingly come to understand that courses of this type are often viewed as falling outside the realm of so-called "real engineering."

In an important sense, the transformative potential of what I have achieved is limited, especially given the position of my new course as an elective that still lives on the edges of the curriculum. Discussing efforts to bring a broader range of skills into engineering curriculum – like design, teamwork, interdisciplinary, and global competencies – Miller even goes so far as to argue that "developing independent new courses in these topics that are separate from the technical core subjects in engineering is not likely to provide an effective mechanism of integration. Instead, if the new subjects are not viewed by students (and faculty) as an integral part of learning to become an engineer, they are not likely to be taken as seriously."[17] Following a similar line of reasoning, Downey adds: "Elective courses supporting the international education of engineers fall on the peripheries of the existing engineering curriculum and show up as line items on the transcript. Their long-term value to students depends upon the will and capacities of students to integrate practices from such courses into their professional practices."[12]

As both of these commentators suggest, elective courses tend to place primary onus on students to relate the technical core of their studies to everything else – which is precisely the challenge I and so many others have faced as undergraduates. And without appropriate guidance and scaffolding, the integration that students do experience is likely shallower, if it occurs at all. Getting the course approved as a university core curriculum elective in the "Science, Technology, and Society" (STS) category – which I did as soon as possible after it was on the books – represented another strategy for boosting enrollments, but it again sends the message that the class is in a marginal position vis-à-vis the core of the engineering curriculum. One modest attempt to address this issue has occurred through revision of the requirements for our College's Global Engineering Minor. My new course is now listed a core requirement for the minor, with the hope that it will serve as a key first step for students wishing to internationalize their education. The minor also includes a 1-credit portfolio requirement as a complimentary bookend to help students integrate their global experiences with all of their other curricular and extracurricular learning.

Yet despite all these efforts, problems of promotion and scale persist. After intensively marketing the course within and beyond the College, eleven engineering students ultimately enrolled. Numerous constraints are likely inhibiting larger enrollments. For example, the new core curriculum requirements are only taking effect with our current first-year students, and many other students and advisors remain uncertain about how the course fits into changing plan of study requirement. In fact, I recently learned that some departments were planning to use some of their pre-existing courses to satisfy the university's new STS core curriculum requirement, thereby removing one of the primary motivators for students in those departments to take a class like Engineering in Global Context. These other courses open up possibilities for enhanced curricular integration, but in all likelihood offer relatively shallow treatments of how engineering and society are related. Given such challenges, I feel a lingering sense of torque still tugging powerfully at me from the shadows of my College. Nonetheless, change comes slowly in the academy, and I recognize that each student in my course represents a kind of success.

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