The Distributed System of Governance in Engineering Education: A Report on Initial Findings

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The Distributed System of Governance in Engineering Education: A Report on Initial Findings

Abstract

Unlike medicine, the engineering profession establishes new standards for engineering education through a distributed system of governance that mirrors the distributed structure of the profession. In this paper, we present our preliminary findings resulting from early data collected through an NSF-sponsored study of this system. This qualitative study is multi-site and multi-scale in its design, and will eventually draw on interviews with faculty and administrators, at different rank, from at least two-dozen different colleges and universities as well as engineering professional organizations. Our interview data is complemented by content analysis of archival documents and published studies, reports, and statements. This paper is designed to introduce our research questions and begin a conversation among engineering educators about how we govern our own educational system. The trends and observations noted in this paper are abstracted from our earliest results, and are described only in general terms. Future papers will explore each of our research questions more fully, taking into account more detailed data.

Introduction

The engineering profession establishes new standards for engineering education through a distributed system of governance that mirrors the distributed structure of the profession. In this paper, we present our initial findings and data resulting from an NSF-sponsored study of this system. This said, just because engineering educators own a defined body of practice for carrying out educational reforms doesn't mean that we know how to coordinate our activities. Few engineering educators are trained in engineering education, let alone the social sciences. Yet, transforming engineering education to serve an evolving social context requires just this kind of knowledge. Given that our work emerges out of a grounded theory tradition (Berg 2001; Strauss & Corbin 1990; Corbin & Strauss 2008; and Star (ed.), 1995; and Clarke 2005), we would be the first to recognize that engineering educators and administrators have amassed considerable knowledge on how to operate in this complex setting. Nevertheless, few engineering educators—or for that matter, historians and social scientists—realize just how complex the U.S. system for engineering education is. (Data in this paper are reported only in general terms, without attribution, with the exception of some data related to the engineering accreditation organization, ABET, still without individual attribution or identifiers, which will be published only following their review and consent.)

To begin with a basic indication of this complexity, the U.S. has engineering degree programs at public and private colleges; comprehensive universities, dedicated engineering schools, and

liberal arts colleges; and rely on an articulated system of education that includes community colleges and extends into various, non-standardized opportunities for continuing professional development and graduate work. We can add to this the fact that we have 50 separate state systems for higher education, significant regional variation in industrial capabilities and their attendant workforce needs, and a variety of federal policies and programs not the least of which is the federal commitment to scientific and engineering research. While scholars such as Ken Alder (1997) have noted how institutional diversity exists even in state-centered systems of engineering education as found in France, the U.S. educational system clearly draws significantly on entrepreneurial energies, going back well before the present neoliberal era. On the other hand, Cold War science policy has also contributed to the diversity of U.S. academic institutions (Geiger 1993, 2015). While this diversity has allowed the U.S. educational system to be highly productive in generating a highly versatile and skilled workforce as well as new knowledge, this can also frustrate efforts to craft uniform visions and standards within engineering education. Even when new standards are established and enforced, the entrenched patterns of institutional diversity will often harbor discontent with the *status quo*, leading to further rounds of reform.

The background research that we have conducted for this study indicates that there are at least three underlying structural conditions that we need to hold as a backdrop for this study (Akera and Seely, 2015; Akera, 2016). The first has to do with the structure of U.S. higher education, as discussed above. The second has to do with the structure of the U.S. engineering profession. And the third has to do with the epistemic habits of the engineers themselves—what engineers regard to be knowledge, and how they are trained to habitually act on that knowledge—and its extension into engineering education reforms.

With regards to the structure of the engineering profession, sociologists of the professions have long ago abandoned the notion that medicine and law are somehow ideal typical professions (Friedson, 1994; Child and Fulk, 1982; Abbott, 1988, 1989). They are, if anything, ideal atypical professions that continue to haunt the conduct of other professions. Thus, although we draw on Magali Larson's (1977) notion of "professional project" to document how and when engineering educators act to bolster their professional image, it is as important to this study that we also employ a basic understanding of the distinct professional configuration of engineering, and how this configuration shapes the profession's educational reform practices. In this respect, the early studies of the engineering profession remain an important point of departure (Layton 1971; McMahon 1984; Sinclair 1980; Reynolds 1983; also Noble 1977); their focus on disciplinary fragmentation and the permeable boundary between engineering and management account for how engineering education appears be pulled in different directions—both within and across organizations.

However, we must also pay attention to the countervailing, more unifying influence of engineering educators and the engineering colleges. Unlike medicine, engineering attracted a body of full-time engineering educators early on, whose professional identification, as educators, rivaled their disciplinary commitments (Carlson 1988; Reynolds and Seely 1993). Historically, this occurred in the United States as a result of its land grant institutions, which expanded educational access and helped establish early standards for engineering education. Over time, this state commitment to undergraduate engineering education also came to lock engineering professional education within the U.S. to a four-year undergraduate model. This said, the four-year undergraduate model of engineering in the U.S. dovetailed with the industrialist's desire to maintain a large STEM workforce (even as the model helped to sustain educational access), with the added benefit to these industrialists that professional training and recognition, outside of Professional Engineer (PE) licensure, could occur through meritocratic standards established within each firm and industry. We should also note that US engineering educators' commitment to teaching has varied with the waxing and waning of an emphasis on external consultancies and sponsored research. Each of these structural elements become manifested as institutional commitments that diverse actors enact as they define distinct trajectories for their chosen initiatives and reforms.

With regards to the epistemic habits of engineers, we are interested in paying attention to how the professional practice of engineering is extended into engineering education in ways that shape how engineering education reform occurs. This includes ways in which established habits for evaluating what constitutes engineering knowledge, or how engineering educators define the problem to begin with give shape to--and sometimes frustrate--their reform initiatives. As an example, given the engineer's stated commitment to always adapting their knowledge to serve "changing times and needs," it should be clear that engineering education is not a problem that can once and forever be resolved. It is, in the engineer's language, a dynamic system that requires constant adjustment in response to a changing environment. Yet many engineering educators approach educational reform initiatives with the elusive hope of "solving the problem of engineering education" through innovative programs and curricula (Akera and Seely, 2015; Pawley 2009).

Also relevant are Seron and Silbey's (2009) findings about risk-averse behavior among engineering educators. According to Seron and Silbey, engineers are professionally trained to manage risk through greater specification, and the extension of this behavior into engineering education compelled them to rely on quantitative standards for accreditation. Although ABET's Engineering Criteria 2000 (EC 2000) reforms during the mid-1990s specifically worked to move accreditation beyond quantitative standards, namely the old "bean counting" approach, the actual implementation of EC 2000's "a-k" learning outcomes at some institutions still wind up in the end affirming Seron and Silbey's findings: the new learning outcomes were often interpreted as a list of requirements to be met, rather than the starting point for a set of institutionally-specific

criteria that would require greater use of professional judgment on the part of both program evaluators and the faculty from programs undergoing evaluation (ABET 2016; also Pool 2016). This simply suggests that the engineer's habit of over-specification can be manifested in different ways. Insofar as we seek to document the reform practices employed by engineering educators, we will need to remain cognizant of the extent to which the prevailing epistemic practices of engineering shape each actor's approach to educational reform—but also how countervailing practices are emerging within engineering education that transcend those limits.

These structural conditions and habits constitute important elements of the distributed system of governance through which recurring changes in engineering education are pursued. On the other hand, our preliminary data reveals, quite forcefully, how none of these structural factors simply determine the course of engineering education reform. The diverse and intersecting character of the structural conditions enable them to serve more as a resource for local, and generally original (highly contingent) initiatives, this at different scales within each organization. This generates diversity in terms of the various approaches to engineering education reform that we see across the multitude of degree programs we have here in the United States. However, it is also our working hypothesis that this complexity, as compounded by the engineer's epistemic habits, make it difficult for engineering educators to effectively craft enduring solutions to the "problem" of engineering education. While the standard for traditional ethnomethodological descriptions of practice may prove elusive in our study (Lynch 1993), we nevertheless aim through a close study of the actual practices of engineering education reform to make a meaningful contribution to the "post-constructivist" literature (Sterne and Leach 2005; Knol 2011); through engagement with constructivism's best critics (Lynch 1993; Hacking 2000), and close attention to practice, we seek to demonstrate how the structural conditions of engineering education define and limit the engineers' diverse approach to educational innovation and reform.

Study Overview

This qualitative study is multi-site and multi-scale in its design, and will draw on interviews with faculty and administrators, at different rank from at least two-dozen different colleges and universities as well as engineering professional organizations, when completed. We are also complementing our interview data with content analysis of archival documents and published studies, reports, and statements. This paper is designed to introduce our research questions and begin a society-wide conversation in the space of how the engineering profession governs its own educational systems. It again avoids all personally identifiable data, and detailed data with the exception of some material from our interviews with ABET staff members and volunteers.

The research questions that define our study consist of understanding and documenting:

a) The basic structure of the engineering profession and U.S. higher education as it impacts engineering education reform initiatives;
b) The historically evolving body of practice that has governed these initiatives;
c) The ways in which the epistemic habits of engineers, such as an emphasis on quantification and measurement, shapes reform agendas and outcomes;
d) The extent to which engineering educators are cognizant of the social and historical contexts within which they operate, and how their articulations of this context come to define dominant directions in reform;
e) The processes through which destabilization and closure occurs in standards for engineering education;
f) More specifically, the mechanisms through which engineering education reform agendas are coordinated (if indeed they are) across different institutions;
g) And likewise, the common mechanisms through which such coordination is frustrated, undermined, and sometimes reversed, especially as a result of institutional diversity and competing agendas.

The following sections delve into these research questions by sub-topic and provide preliminary analyses and answers to each. As a preface, we note that our team is still at the earliest stages of conducting interviews; especially given the small sample size, and our obligations to maintain confidentiality, no detailed, or individually or institutionally identifiable results will be reported in this paper with regards to our university participants. Some references will be made to ABET and other organizations, either based on publicly available information or else through their review and consent before this paper is released in its final form.

Structure

What is the basic structure of the engineering profession, and of U.S. higher education as it impacts engineering education, and how do they enable and frustrate engineering education reform efforts?

Our interviews to date affirm the impact that the basic structural features of the engineering profession and its configuration have on educational innovation and reform. For example, the tension between disciplinary specialization and a more unified engineering curriculum discussed above is already amply evident in our data. Both for institutions seeking to create distinctive, highly ranked programs in engineering, as well as those seeking to create credible undergraduate engineering programs that maximizes access while also expanding the national STEM workforce have struggled to balance professional skill sets with fundamental training in engineering in a manner that gives a distinct profile to each program. Our initial data indicate that U.S. universities continue to struggle to define themselves at this nexus.

It is also evident that the various "structural" features that we reference in our study design function in complex, interdependent, and generally non-deterministic ways that approach the complexities of an ecosystem. For example, while much of the focus on professional skill sets—especially teamwork, communication (writing and presentation), and design—have occurred within traditional coursework (this quite likely as a result of ABET's Engineering Criteria 2000 reforms), many programs are now also pursuing co-curricular programs and initiatives, such as makerspaces, entrepreneurship, study abroad experiences, and undergraduate research, in ways that occur outside of coursework and find unique expression at each institution. Significant differences in implementation exist, even though they all draw on known national trends. Relevant also to the conversation about practice, below, there is a good deal academic entrepreneurialism to be found at many universities, where initiatives are designed to be visible to external donors as well as students and parents. Adaptive responses to the complex set of circumstances that shape each institution suggests that a basic ecological metaphor, as opposed to a structural metaphor, may more properly characterize how engineering education operates as a system.

Reform Practice

Is there an ethnomethodologically accountable (describable) body of practice for engineering education reform? What are the origins of this body of practice, and how has it changed over time? Can these historical and contemporary practices be described at least in outline, if not with the full diversity and detail as found in traditional ethnomethodological accounts?

More unique to our study, we have been working to document the distinct body of practice that constitutes the ways in which we transform engineering education here in the United States. This second research question is informed by the social scientific tradition of ethnomethodology, and specifically its application to science studies, and by extension, engineering studies (Lynch 1993). As consistent with the phenomenological grounding of ethnomethodology, the goal here is not to reveal some kind of esoteric practice that defines engineering education reform, but to locate and describe the very ordinary, everyday actions that constitute people's efforts to change engineering education.

From our historical work, we already know that engineering education reform began by borrowing extensively from Progressive Era reform traditions in education at large. As funded by the Carnegie Foundation for the Advancement of Teaching, the earliest of the Society for the Promotion of Engineering Education's (SPEE, now ASEE) major studies, the Mann Report (1918), was conducted in the very manner that other comparable studies of education were being conducted, including, notably, the Flexner Report in medical education (1911), funded by the same organization. This study and subsequent support by the Carnegie Foundation enabled SPEE, which became ASEE in 1946 to develop an internal capacity for carrying out "grand investigations" that produced, among other things, the Grinter Report (1955) and the Goals

Report (1968). Later studies by ASEE, including the Green Report (1994), as well as key studies produced by organizations such as the National Science Foundation (1995); the National Academy of Engineering (2004; 2005); and ASME (2011) were produced through analogous processes that have become part of the familiar landscape for how we in engineering education "do" reform.

This said, these grand national studies are hardly the be all and end all of our efforts to transform engineering education. Our initial data reveals quite definitively how a basic commitment to change exists at every level within U.S. universities, and within the broader ecosystem of engineering education. This is not to say that every engineering educator is committed to change. Within research universities a relatively small percentage of faculty members demonstrate a serious commitment to teaching, let alone educational reform. At private teaching colleges there is, on the other hand, a distinctly higher percentage of faculty who are firmly committed to their students' educational experience. Many self-identify as being involved with educational reforms, though not necessarily at the national scale. This said, as part of their everyday, ordinary actions, engineering faculty at every kind of institution are constantly introducing new content, and trying their hand at new tools and techniques such as a new learning management system or flipped classrooms. Departmental curriculum committees, although to a varying extent, have established methods for reviewing and updating their curricula; some faculty are also involved in nationally organized efforts to develop model curricula. Voluntarism, at the national level, also remains a major feature of engineering education, both with regards to initiatives organized by the engineering professional societies, as well as by volunteer, service-based organizations such ABET. As we move up the chain, it's evident that engineering deans have a variety of forums for exchanging information and assessing their competitive position. Meanwhile, executive directors and key staff members within national organizations plan and orchestrate educational change using both well-defined bureaucratic practices as well as more improvised organizational maneuvers designed to spearhead change.

While it is too early for us to speak to how these processes intersect, our work reveals that understanding the interactions that occur between the macro and micro levels (or more likely, macro, mezzo and micro levels) will be essential to understanding the efficacy of any given reform effort. We have already seen multiple instances where there is an evident disconnect between a policy at the national level, or initiatives at the provost or engineering dean's level, and the initiatives being actively pursued by the faculty. This generally results in wasted effort. The different visions of the engineering profession, as advanced especially by different engineering professional societies, can also become debilitating, and this can enable secondary or external agents to exercise a greater influence on the overall direction of an educational reform initiative. We need more data about how institutions interact with one another in order to better understand what's needed and what's possible in coordinating change in engineering education.

Epistemic Habits

What epistemic habits do engineers have that influence their approach to engineering education reform? To what extent do these habits originate with, and are contiguous with the disciplinary training, background, and habits of engineers (e.g. measurement, quantification, over-specification, problem solving orientation, survey research)? To what extent do they have other origins?

Conjoined with our interest in ethnomethodology and the practice of engineering education reform is a more specific research question having to do with how the epistemic habits of engineers influence how they go about pursuing educational reform. Foundational in this respect is the article by Seron and Silbey (2009) that posits the claim that engineers have a quantification bias; their specific argument is that engineering educators have a habit of wanting to reduce risk and uncertainty as a result of their professional commitments, and that they will frequently choose quantification as a means of arriving at more definitive measures of what anything they assess. Speaking of this as "Type II error" of over-specification, and addressing specifically accreditation standards and how this affects engineering education and professional standing, Seron and Silbey assert that engineers undermine their professional claims by routinely rejecting more meaningful measures that requires them to exercise professional judgment.

Our interview data, part of which focuses on the historical development of Engineering Criteria 2000 (EC 2000), suggests that this kind of quantification bias may be alive and well in engineering education. In first confirming Seron and Silbey's assessment, a quantification bias was clearly built into the engineering accreditation practices employed prior to EC 2000; many interview subjects were reflexively aware of this fact. However, even after EC 2000, it is clear that the habits of over-specification could creep back into the new accreditation practice, namely outcomes assessment. While the intent of EC 2000 was to move beyond rigid, quantitative standards, there are programs that take a fairly narrow approach in assessing the defined ("a-k") outcomes specified under EC 2000. And while programs were originally encouraged to define program objectives that were unique to their institution, and merely map these onto the a-k criteria, the added layer of uncertainty introduced by this act of translation, as well as the professional judgment required by ABET's program evaluators and the faculty from programs undergoing evaluation prompted most institutions to abandon this extra step. While this is but one example from our early data, it appears that despite important changes, the assessment and evaluation practices for engineering accreditation remain to some extent aligned to the epistemic habits of engineers.

Our initial data also suggests that the epistemic practices associated with measurement, quantification, and the reduction of uncertainty can be found more extensively across other aspects of engineering education. One obvious manifestation of this phenomenon is the typical engineering school's obsession with rankings. Despite the many critiques that exist of national

ranking systems such as that of U.S. News and World Reports, references to rankings pervade many conversations, especially among administrators at highly-ranked institutions. Even faculty who insist on the violence done by rankings speak of how rankings play a necessary role in the resource planning and allocation decisions of their institution. The fact that epistemic habits of engineering ground our efforts to "reengineer" higher education presents us with another major line of inquiry, one for which we still have limited results.

Articulations of Context

To what extent, and in what manner do engineering educators and their leadership contribute to articulations of the social context to which they direct their reforms? Are national agendas such as "engineering manpower crisis" or "national competitiveness" simply inherited, or do engineering educators and other members of the broader engineering community contribute substantially to their articulation? Even if inherited, what practices are invoked in translating these social concerns into concrete changes in engineering education and curricula?

We decided early on in our project to divide this question into two separate questions, first about how broader social and political economic contexts shape engineering education reform, and through their implementation give specific meaning, or "articulation," to a broader movement in society; and second, about how developments within engineering education might contribute more directly to broader national conversations, especially as they relate to higher education reform.

Occurrences of the former have been easy to ascertain. The focus on engineering science—a science based approach to engineering education and research—came into ascendance during the Cold War, most notably through the Grinter Report (1955). Then with the waning of the Cold War, conversations about U.S. industrial productivity (1970s), national competitiveness (1980s), and now economic globalization (1990s and beyond) have led to a softening of the engineering science agenda. We can better appreciate, in retrospect, the controversial recommendation found in the first draft of the Grinter Report (1953), which called for a bifurcated system of accreditation based on recognizing the difference between "professional-general" and "professional-scientific" programs. While this recommendation was soundly rejected by institutions who rightly saw this as a two-tier system of accreditation, it nevertheless mapped onto a Cold War reality in which certain institutions shifted aggressively to science-based curricula, while others retained, at least for a while, were not immediately inclined to shift so quickly away from engineering practice. By rejecting bifurcation, nearly all institutions were compelled to shift to more science-based curricula, this through new accreditation standards imposed by ABET's precursor, the Engineers' Council for Professional Development (ECPD).

One of the striking things from our data is the realization that quantitative standards for accreditation were exactly what was needed to force the rapid expansion of the engineering

sciences in undergraduate engineering curricular during the early years of the Cold War. By the same token, the continued commitment of leading research universities to science based curricula guaranteed that the EC 2000 reforms that emerged out of the national competitiveness debates could not simply be achieved through a quantitative reallocation of curricula. But this meant that schools that began to make curricular changes in response to a shift in the political economic climate, specifically by increasing their focus on professional skills sets and more integrated forms of engineering knowledge directly hit up against the rigidity of the quantitative standards built into ABET's pre-EC 2000 criteria. Disagreements erupted specifically over the issue of professional judgment, as program evaluators and those representing the programs undergoing evaluation had to navigate the difficult terrain of whether changes produced shortfalls in the defined standards. The relationship between ABET and the programs undergoing evaluation became adversarial, enough so to pose a threat to the credibility of ABET and accreditation.

EC 2000 was a bold maneuver designed to restore ABET's credibility, as achieved through a historic compromise. To appease those who continued to hold basic quantitative expectations regarding engineering curricula, EC 2000's architects agreed to retain a basic, quantitative definition of engineering curricula—a year of math and science, a year-and-a-half of "engineering topics," a half-year of integrated design experience, and a general education component (no longer quantitatively specified) designed to round out the technical curricula. It also left the evaluation of this content squarely in the hands of program evaluators selected by the professional societies assigned to evaluate the specific degree programs, with instructions to do so based on the standards and expectations of their discipline.

However, with regards to professional training in engineering that was independent of the disciplines, EC 2000's architects defined a separate set of "student outcomes" that focused primarily on the professional skill sets--teamwork, communication, professional and ethical responsibility, designing systems that met social, political, and economic constraints, a commitment to lifelong learning, etc…--that were consistent with the "desired attributes" of an engineering graduate in the post-Cold War era. In its practical implementation, these became Criterion 3 (student outcomes) and Criterion 4 (in the original version, now Criterion 5 (curriculum)).

This was an arrangement that recognized that the expansion in professional skill sets had to occur, at least in large measure, through existing engineering courses. Especially given the decline in public commitments to higher education, and the associated pressure to drive down the total credit hours at public universities, there was little chance that these new skill sets could be delivered through new courses added to the curriculum. While the liberal arts faculty, at some institutions, could be compelled to develop more professionally relevant courses, and some institutions moved in this direction, most universities, with strong liberal arts faculties that

continued to attend to their own majors, moved only marginally in this direction. EC 2000's Criterion 3 was, in any event, a proactive and proscriptive document. Its emphasis was on professional skill sets found lacking due to a shift in economic content, and was never intended as a carefully specified list of all of the attributes of a solid engineering education. It was in fact based on pressure from, and an assessment produced by a group of leading industrial employers. These attributes were then paired with new mandated procedures for assessing student outcomes.

This points to another aspect of recent changes that are visible in our early findings, namely the extent to which the engineering education reforms that have occurred since the 1980s have been animated by neoliberal principles. Following Aihwa Ong (2007) and Loïc Wacquant (2012), we consider neoliberalism not to be a single unified doctrine, but a malleable political economic philosophy designed to facilitate the spread of market institutions and practices into the public and civic sphere. So for instance, at the heart of EC 2000 has also been an effort to move away from a fixed set of educational outcomes to a more flexible approach grounded in the quality management movement that was unfolding during the 1980s, also as a result of concerns about U.S. manufacturing productivity and national competitiveness. To maintain our focus on developments outside of EC 2000, we might also note that the current obsession with external metrics such as the U.S. News and World Report rankings, and the purported value that such measures have for student recruitment, retention, and the financial profile of our educational institutions demonstrate the broad diffusion of market-based strategies for sustaining and directing our educational institutions. Again, our results here are quite preliminary, but we hope to trace more carefully how, and as importantly, to what extent the broader political economic "context" of neoliberalism has influenced engineering education within the United States.

Other national conversations about engineering education reform have also served as an important context for more local initiatives. Our data suggests that studies such as the National Academy of Engineering's *The Engineer of 2020* (2004) and ASME's Vision 2030 (Kirkpatrick, et al., 2011) have served as a catalyst and a focal point for local initiatives, but have rarely led to specific implementations. The NAE Grand Challenges, and especially the Grand Challenges Scholars Program has had a more direct impact on the shape of local reform initiatives, but even there, the Grand Challenges operate primarily as a touchpoint for open discussions about general project ideas. Those interviewed indicate that a program such as the Grand Challenges helped to direct their attention, but not to the point of determining the specific ways in which they built their programs.

Regarding the separate question of whether, and in what ways developments within engineering education contributed to the articulation of significant developments in higher education, the most interesting artifact so far has been the development of learning outcomes assessment within and beyond engineering. The shift from a focus on "inputs," namely teaching and curriculum, to a measurement of learning outcomes originated outside of the United States in the realm of K-12

education. During the early 1990s, K-12 educators as well as the regional accreditation agencies for higher education were considering a shift to learning outcomes, but the latter had yet to act. Our interviews with current and former ABET officials suggests that outcomes assessment in higher education was first implemented on any significant scale in the realm of professional education, specifically in business, nursing, and engineering.

Developments within business and nursing apparently preceded those within engineering, and EC 2000's architects followed these developments closely. This said, the fact that ABET was receiving considerable pressure to shift the focus of accreditation to professional skill sets, and were given a specific list of desired attributes by an influential group of industrial representatives suggests that those affiliated with EC 2000 had already received a mandate to assess and verify that students were graduating with a specific skill set. Those who developed EC 2000 may not have given all that much thought to how they would carry out assessment prior to rolling out EC 2000. Nevertheless, the fact that outcomes assessment became a routine practice within the nation's engineering colleges must have provided compelling evidence to the regional accreditation agencies that such a shift in higher education was possible. The exact nature of that connection remains to be ascertained through further interviews and research.

We will be looking for other ways in which developments within engineering education contributed to broader changes in higher education. While we so far have very little in our data set, the widely touted concept of "reengineering" higher education, with its semiotic reference to engineering, suggests how engineering mindsets, and other specific practices beyond outcomes assessment may have come to permeate higher education as a result of changes within engineering education. Historically, we know that STEM workforce issues, in their many different rhetorical manifestations, have been an important cornerstone of national higher education policy. From the 1862 Morrill Act and its focus on educational access and the mechanic arts; to the 1958 National Defense Education Act as constructed in response to Sputnik; to the 1960 California Master Plan for Higher Education and its role in creating one of the most envied and emulated higher education systems in the world, developments within STEM education have brought about significant shifts in higher education.

Thus, we would want to trace the extent to which current efforts to transform engineering education amount to a broader transformation of U.S. universities, one more suited to current concerns surrounding economic globalization. The very fact that changes in U.S. engineering education have been anchored by a very active, voluntarist traditions also deserves comment. This trend is consistent with neoliberal principles that circulate in the present era, and can be contrasted with the national response that occurred in response to Sputnik. It might also be compared to the Bologna Process in Europe, where there is clearly a more government-led effort to transform European university systems into something still aligned to developments within the global economy.

Coordination

How are changes in engineering education coordinated across the distributed field of organizations that have responsibilities for, or else have substantial input with regards to new directions in engineering education? How are responsibilities defined or delegated across organizations? Both in the past and present, who assumes leadership over educational reform? Who is excluded?

In this paper, we have been responding to our research questions in the order in which we posed them. While this breaks up some of the narrative developments, this early report is designed to draw attention to the constituent phenomena that remains the focus of our study.

Given the distributed nature of authority within the engineering profession, coordination is one of the other, particularly important themes in our study. Our preliminary data suggests that coordination remains limited, and uneven within the U.S. system of engineering education. Accreditation does emerge as an important mechanism for coordination. It remains the primary vehicle for maintaining minimum standards within engineering education, and it has been used to drive basic changes in engineering education—both the ascent of engineering science during the 1950s, and the attendant shift towards professional skill sets during the 1990s, both as described above. Even within ABET, however, there are those who ask whether a significant reorientation within engineering education might have happened anyway in the absence of decisive action on the part of their organization.

It terms of the formal governance structure it is important to note that ABET is set up as a delegate-based organization. There are no individual faculty members who belong to ABET; professional societies hold one or more seats on ABET's Board of Delegates as well as within each of the four accreditation commissions (engineering, engineering technology, computer science, and applied and natural science; the number of seats within each body are based on the number of degree programs that are evaluated in their area.) This said, the Board of Delegates is perceived to be too large of a body to make effective decisions, and not all delegates have the requisite background and training to effectively represent the interests of their professional society. The Board of Delegates previously served as ABET's Board of Directors, but a smaller Board of Directors comprised of just 12 members was created specifically to address this concern. In practical terms, ABET is able to function because many, and more likely a majority of the volunteers identify primarily with ABET, and not only with their professional societies. This is especially true for those serving on the Engineering Accreditation Commission (EAC), as well as the other commissions and their subcommittees who attend to the operational needs of ABET and have a long history of working to uphold its organizational mission. This said, certain compromises are struck to ensure that the curricula, learning outcomes, and the policies and procedures developed by ABET can be "sold" back to the professional societies' governing body

by their respective delegates. It appears that the delegates are generally entrusted with this responsibility, although when society-specific concerns surface, the delegates also surface as important vehicles for expressing specific concerns about prevailing or proposed standards and policy changes.

This said, it appears that a good deal of change and innovation in engineering education occurs through local initiatives that occur outside of ABET's purview. Especially notable are the many initiatives, such as makerspaces, entrepreneurial opportunities, and undergraduate research experiences that are designed to be visible to external donors and students. Insofar as these initiatives are driven by objectives such as recruitment and retention that do not necessarily map onto ABET's emphasis on learning outcomes applicable to all graduates, they rarely align with the mandated assessment protocols designed by the institutions and programs undergoing evaluation. As mentioned above, here national studies such as the NAE Grand Challenges are more likely to serve as inspiration for local action.

There is also a considerable extent to which institutions model what they do based on initiatives that are already taking place at "peer and aspirant institutions." Many universities in fact engage in the routine practice of assembling study teams when launching a new initiative, and these teams are almost always welcomed at the colleges and universities that have already implemented successful programs. Academic traditions of openness appear to contribute to a general ethic of sharing. In addition, accreditation visits themselves serve as an important mechanism for faculty to see what peer institutions are doing in their area. The level of transparency mandated by accreditation does stand in sharp relief against the proprietary treatment of knowledge within the corporate sphere, where audits are generally limited to financial records.

Diversity & Closure

Specifically, is this coordination frustrated because of different goals and perceptions that exist within the different levels of an organization? Across organizations? What practices exist, both formal and informal, for managing diverse constituencies and divergent attitudes about engineering education? What processes are or have been employed to bring closure to a reform initiative?

Our data and the discussion above all point to the fact that the U.S. system of engineering education is tremendously diverse; it is in fact constituted as a highly complex ecosystem with many interdependent parts. Going back to the Wickenden Investigations of the 1920s, there has been the broad recognition that engineering education is not limited to the 4-year undergraduate degree, but other programs that precede, follow, and complement it (SPEE 1930, 1934). In William Wickenden's time, the basic structure of what we would now call STEM education was organized around technician training, undergraduate education, and corporate training during the

post-graduate years. Today, our system depends heavily on associate's degrees; undergraduate programs in engineering and other aligned disciplines (including engineering technology); graduate education and post-doctoral training; continuing education and corporate training programs. Not unlike other professions such as healthcare, our overall system of engineering and STEM education depends on the complementary functions delivered by a wide variety of institutions that vary in composition, orientation towards access, and rank. This said, questions remain about whether these different components are balanced.

With regards to how closure around new educational standards occur in spite of this diversity, much of the discussion up to this point remains relevant. Orchestrating closure around new engineering education standards requires careful coordination across the diverse institutional entities found within the realm of engineering education. This is not to say that this conversation occurs on a level playing field. During the ascent of engineering science during the 1950s, there was an elite group of engineering deans, primarily from a number of private universities and large state universities, who dictated the change in educational standards. Operating through both the Engineers' Council for Professional Development (ECPD) and the American Society for Engineering Education (ASEE) and its Engineering Deans' Council (EDC), this group orchestrated the shift to quantitative standards that placed strong emphasis on engineering science (Akera, 2016).

Our initial data suggests that EC 2000 emerged through a different process. Instead of the process being driven by an elite group of engineering deans, there was broad discontent on the part not just of the academic programs that were faced with outdated quantitative standards, but industrial employers and the engineering professional societies, all of whom were responding to a change in national priorities. The dissolution of the consensus around engineering science nevertheless produced an impasse, as the member societies and their delegates to ABET adopted different positions. It appears that this impasse may have allowed a select group of volunteers within ABET to foreground the concerns expressed by major industrial employers in order to create a viable path forward.

It also appears, in this instance, that the National Science Foundation (NSF) and the American Society for Engineering Education (ASEE) played a not insignificant part in helping to orchestrate the conversation that brought the divergent parties back together. The process began when the ABET leadership agreed in 1992 to convene an Accreditation Process Review Committee comprised of both ABET and non-ABET representatives. This was followed by a series of NSF-sponsored stakeholder workshops in 1994 to further deliberate on three areas--criteria reform, accreditation reform, and stakeholder influence or "participation," as it was called. ABET's Board of Directors approved the workshop recommendations in principle, and instructed the Engineering Accreditation Commission to assemble a set of committees that were formally charged with finding a way to act on the recommendations.

The idea to shift to learning outcomes emerged out of the Criteria Committee. While the initial response to the proposed changes, first released to the EAC during the summer of 1995, was apparently contentious—there were serious concerns about how the proposed change would be implemented—the ABET Board of Directors (under the old delegate structure) in this instance intervened, and after just one-year of public comments, approved the new criteria for a staged trial and roll-out. While the exact reason for the Board's rapid action remains unknown, it is clear that the governance structure in this instance worked. The Board did move forcefully to support the work of a committee that it felt offered a credible response to the charge given to it. This said, further effort to orchestrate consent occurred during the trial period of three years, during which 2, 4, and 8 (or by one account 12) programs, respectively, underwent evaluation, which generated evidence indicating that outcomes assessment was a feasible in engineering education (See also Prados, Peterson and Lattuca, 2005).

Destabilization

How and under what conditions do prior arrangements become destabilized? To what extent are the recurrent cycles of reform in engineering education driven by external factors ("changing times and needs"), and to what extent are they driven by an organizational logic (especially bureaucratic procedures), or else through reform impulses that are internal to the epistemic culture of engineering education?

We again need to be careful as to whether the ordering of our research questions produces a narrative arc about how change happens that may or may not be an accurate representation of how changes in engineering education unfolds as a whole. Specifically, although we address destabilization as the last phenomenon discussed in this paper, it should not be taken either as a necessary endpoint or starting point for reform. We simply posed destabilization as our final research question only because there were prevailing concerns about ABET's engineering accreditation criteria, and because disagreements surfaced during ABET's recent efforts that resulted in changes to the criteria. In this paper, we take this development simply as one case study in destabilization.

Our initial data points to the fact that ABET had not given all that much thought to assessment when it first approved EC 2000. Of considerable concern at the time to those at ABET, the Association to Advance Collegiate Schools of Business (AACSB), which had unfurled outcomes assessment prior to ABET, was suffering heavily from the fact that they had offered little guidance on how to conduct assessment. This prompted ABET to institute a series of regional assessment workshops directed to the faculty at institutions that were scheduled to undergo evaluation under the new accreditation standard. Despite this, there remained considerable concern, primarily about workload, but also about other issues such as program evaluator training and the consistency of evaluations. This prompted ABET, during the early 2000s, to

support a major study be Pennsylvania State University on the impact of EC 2000. They also convened an open forum at Worcester Polytechnic Institute to demonstrate their commitment to identifying and addressing problems that remained with implementation.

While this was done to shore up the validity of ABET's new approach to accreditation, the focus on training, especially for faculty at programs undergoing evaluation, presented something of a quandary, one directly relevant to our present conversation about destabilization. While the regional faculty workshops and other workshops conducted by ABET and its consultants helped convince universities that outcomes assessment was in fact feasible and doable, the presentation of best practices, which some schools were quick to take up as a recommended assessment protocols, as opposed to one possible implementation, worked against the emphasis on continuous program improvement, and the development of program objectives and unique assessment instruments matched to those objectives. While standard protocols might have been suitable for both new and lower-tier institutions seeking to demonstrate that their degree programs met a minimum threshold, these assessment protocols did not necessarily align with the innovative educational initiatives that could be found at more established, higher-tier institutions. While standard assessment protocols might still be sufficient to pass an accreditation review, such mechanical implementations of assessment contribute little to program improvement, even though continuous improvement was intended to apply to all institutions, regardless of their rank and stature.

In interviews, ABET staff members report that a majority of the institutions and programs undergoing accreditation use assessment to drive meaningful changes within their program. Those at ABET nevertheless recognizes, and our early data affirms that there are also institutions that take a more mechanical approach to assessment. This does not mean that such programs do not work to improve their programs. However, educational improvement and innovation at those institutions might occur through other channels, such as through faculty efforts to produce model curricula in conjunction with their professional society. We need to substantially expand our data set before we can provide a more robust picture of the different ways in which institutions are presently engaging with assessment. There were also other reasons for discontent to emerge around engineering accreditation. From our interviews, such a list would begin with concerns about faculty workload, program evaluator training, and the consistency of evaluation outcomes. None of these were foreign to ABET--considerable effort has been invested in improving program evaluator training, for instance. This said, uneven engagement with meaningful assessment introduces a layer of complexity and uncertainty to both training and the actual accreditation visits.

These were the factors that prompted ABET to begin thinking about a general review of its engineering accreditation criteria, with it being said that the earliest conversations on the topic beginning sometime around 2007 (this despite some early discussion that EC 2000 would not

seek any serious changes to the standards until two full cycles of accreditation had passed). In 2009, the Engineering Accreditation Commission made a formal decision to constitute a task force to initiate a general review of Criterion 3.

From the standpoint of our project and that of organizational sociology, the most interesting thing about these developments is that when accreditation criteria were being driven by powerful institutional actors, the focus of reform was very clearly about engineering professionalism and the need to adapt the U.S. engineering workforce to meet new global economic realities. When the articulation of needs was passed down to a task force several layers down within the organization, operational concerns dominated, with a focus on removing or redefining those outcomes that were proving especially difficult to measure or achieve. To its credit, ABET's Engineering Accreditation Commission, as well as the Criteria Committee itself, substantially revised the initial recommendations of the Criterion 3 Task Force, restoring many of the professional skill sets that were removed or deemphasized in an early, draft version of the proposed criteria. This said, ABET also points to the importance of the recent revisions in modifying or clarifying requirements in ways that offer better guidance to both program evaluators and the programs undergoing evaluation.

Continuing the Investigation

This paper is merely a preliminary reporting of our findings. While we have offered various speculations as to the nature of engineering education reform as is discernible from our initial data set, and spent a little more time reporting on our findings about ABET, [would like to add: with their review and consent,] our data set is too sparse to offer any real conclusions. With this paper, we sought instead to introduce our project and its research questions, and evidence that the data needed to answer our research questions existed and could be collected through historical and qualitative (semi-structured) interview methods.

Some areas in which we will focus our future data gathering efforts include the following with regards to each of our research questions:

- Structure: Developing a better understanding of the structural influences on engineering education reform, and the ways in which local initiatives draw flexibility from the complex ecosystem that comprises the system of engineering education in the United States.
- Reform Practice: The ways in which the myriad ordinary practices of education and educational reform, as carried out across the different organizations within the U.S., interconnect the institutions within the engineering education ecosystem, and produce both dominant and counter-hegemonic directions in reform.

- Epistemic Habits: A better understanding of the various ways in which risk averse behavior and quantification shape how engineering educators approach reform. A search for other epistemic habits of engineers that shape their educational innovations and reforms.
- Articulations of Context: To continue to refine our understanding of the post-Cold War (and through historical sources, the Cold War) transformation of engineering education, and this transformation gives specific meaning to the broader social and political movements characteristic of these eras. Likewise, to refine and expand our understanding of how developments within engineering education have contributed to broader changes in higher education.
- Coordination: Addressing more specifically how coordination happens--and doesn't happen--across engineering professional organizations and educational institutions, and to expand our data set beyond ABET to document the influence of other organizations including the National Academy of Engineering, NSF, the major engineering professional societies, and ASEE itself.
- Diversity & Closure: Likewise, moving beyond ABET to document how consensus emerges around initiatives such as makerspaces, entrepreneurship, undergraduate research, and study abroad experiences, but also instructional techniques such as distance education and flipped classrooms. Understanding how the diversity of U.S. engineering education institutions both facilitate and limit closure in the specific instantiation of such initiatives.
- Destabilization: Documenting the more diverse ways in which predominant initiatives within engineering education lose momentum, and the process by which attention shifts to other, newer initiatives.

This is by no means an exhaustive list of the questions we will be asking as we move forward with our study. Our research protocol calls for a continual assessment of data to further refine our interview questions and data gathering efforts, including subject selection. It remains our goal to produce insights that are immediately useful for all those engaged in engineering education reform. The hope, as we expressed in our proposal to NSF, is to move well beyond a descriptive enterprise in coming up with a tangible product—specifically, a concise and widely distributed booklet in addition to academic articles—that will offer practical guidance on how to bring about more efficient and enduring solutions to the many challenges of engineering education. We look forward to reporting on our progress again next year, and to the early impacts of our study.

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