AC 2012-4144: THE TYRANNY OF OUTCOMES: THE SOCIAL ORIGINS AND IMPACTS OF EDUCATIONAL STANDARDS IN AMERICAN ENGINEERING

Prof. Amy E. Slaton, Drexel University

Amy E. Slaton is a professor of history at Drexel University. She is the author of *Race, Rigor, and Selectivity in U.S. Engineering: The History of an Occupational Color-Line* (Harvard University Press, 2010). She also writes at the website STEMequity.com.

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Abstract

As we leave behind “No Child Left Behind” for new educational policies in the United States, questions about the value of punitive applications of educational standards have gained attention. As a nation, we are actively questioning how best to use systematic assessments of individual students, programs, schools, and school systems; “carrots” today seem more inspiring than “sticks” to many concerned about our schools. But few if any observers have considered that by definition, *all* attempts to prescribe outcomes or establish performance standards may discourage criticality to some degree, constraining inquiry into radically innovative practices or goals. This paper considers the nature of outcomes-based credentialing practices in U.S. engineering education to identify ways in which alternative pedagogies and applications of engineering might be foreclosed by these “best practices,” however well-intentioned. It focuses on ABET formulations regarding undergraduate engineering since 1980 as a set of epistemic and socially regulatory instruments. Analyzing both the purported function and the content of outcomes included in ABET documents over the last three decades, the paper shows how ABET has projected a formative role for outcomes in curricular development and institutional credibility. In particular, impacts of ABET outcomes-focused practices upon diversity, public participation, and the pursuit of social justice in engineering education (and thus in the profession of engineering) will be examined. ABET has often stated its commitment to such socially desirable aims. Drawing on the sociology of knowledge and related methods of studying the institutional conservatism of performance standards, we may recognize the challenges to change inherent in outcomes-focused education and increase the likelihood of achieving those aims.

Introduction

This paper considers a tension inherent in higher engineering education in the United States. On one hand, the discipline has for many generations stated its commitment to societal betterment, ethical responsibility, and democratic ideals. The improved health and safety of the public, responsible business conduct, and more recent issues such as environmental sustainability are among such ideals. These are the aims that give rise to such pedagogical elements of university engineering curricula as “critical thinking,” or a stress on “societal context.”^{1,2} On the other hand, we might also see in engineering education a tendency to deny the undemocratic conditions that presage or arise from the work of engineers; that is, a closing off of deeply critical or wide-ranging thinking about societal needs or ethics by engineering teachers and learners.³ In this essay, I consider how “Student Outcomes,” as expressed in ABET’s current accreditation requirements under “Criterion 3,” embody this contradictory set of impulses in contemporary American engineering.⁴

It is important to begin this discussion by noting that the ethical and societal commitments of individual instructors and students, or of the leaders of such influential bodies as ABET, the National Academy of Engineering, or the American Society for Engineering Education, are not in question. We cannot presume to know what any individual thinks without asking her or him, nor whether the pronouncements one might make in a professional capacity reflect one’s own

beliefs. Instead, this paper considers how the formal expression of professional aims embodied in ABET's accreditation criteria, in university engineering department documents, and in writing on those criteria by educators, helps to promote certain, ideologically narrowed approaches to engineering. Specifically, I want to suggest that the framing of societal concern or critical thought about engineering as "outcomes" is itself problematic, constituting a process of accountability that leaves little possibility for profound critique of the field. In essence, the determination of how well or poorly these outcomes have been achieved, through assessment of the performances of engineering students, discourages the kinds of questions about societal privilege and profit that would have to be asked for engineering to be understood as the thoroughly political and social activity many social scientists and some engineers believe it to be.⁵

This discouragement arises from both the content and deployment of the eleven outcomes included in Criterion 3.⁴ In terms of content, three of the outcomes seem to call explicitly for student inquiry into engineering in critical terms; that is, as a matter of listening to what Oberst and Jones see as the "increasingly loud voice of the social imperative" that today surrounds technical work.^{6,2} These outcomes are:

- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- (j) a knowledge of contemporary issues

Three others imply a need for collective thought or open-ended interchange that could conceivably support awareness of different social viewpoints:

- (d) an ability to function on multidisciplinary teams
- (g) an ability to communicate effectively
- (i) a recognition of the need for, and an ability to engage in life-long learning⁴

These six outcomes are sometimes referred to as the "professional" aspects of engineering education, as opposed to the "hard" aspects.² The five so-called hard outcomes by contrast explicitly encourage a narrower, more instrumental stance for engineering students (for example, those requiring in students "an ability to identify, formulate and solve engineering problems" and "an ability to design and conduct experiments, as well as to analyze data") and we may consider how these latter goals conceptually override the previous ones.

This focus on processes of assessment and accountability reveals longer term ideological commitments of engineering, many historically formulated in service to the corporate, military or governmental institutions in which engineering is normally deployed. Ironically, Outcomes A-

K, closely associated by proponents with a nimble and vigorous response by U.S. interests to global markets⁷, seem to support a kind of political closure on the part of learners³; what educational theorists might refer to as cultural assimilation.⁸ Their very invocation--the pervasive appearance of the Criterion 3 "Student Outcomes" on the home pages of American engineering departments, as a kind of boilerplate--signals particular adherence to convention. By definition, a choice to pursue accreditation means that a school on some level accepts ABET's idea of best practices, and this paper will touch on the conservative social function of this system of professional self-scrutiny.

Again, we should proceed with caution in any effort to characterize politically or ethically American engineering education, in general or in the cases of particular programs. The general flavor of ABET's student outcomes as written (notably devoid of particularities), follows from ABET's stated and welcome intention to replace the "bean-counting" function of its previous accreditation criteria with more open-ended and flexible prescriptions. What might constitute optimal student instruction or assessment for any of these desired 11 outcomes is not specified in ABET documents, any more than are precise standards of "health," "safety," or "sustainability." As Shuman, Besterfield-Sacre and McGourty have put it, this deliberate vagueness reveals an appreciation on ABET's part that engineering "is highly situationally dependent" and helps offset historical tendencies for engineers to cast their profession (as John Prados phrased it) as one of "all knowing experts."^{2,9} We will see other evidence that equitable, inclusive and ethical engineering is the intended result of ABET's "A-K," as these outcomes are informally known. Without question, in many schools, classes in which social scientists, activist engineers, and ethicists play a role do bring deeply critical questions to American higher engineering education. I sincerely hope that my own history courses within an engineering school achieve such results. Yet, I will also show that the position of criteria c,h,j,d,g, and i *amidst* the more narrowly instrumental goals outlined for engineering education, and their application within assessment systems by engineering departments, powerfully dictate social normativities for engineering students. In many cases, features of social context and issues of positionality (that is, distributions of the privilege or costs associated with modern engineering among different social groups) are marginalized in American engineering pedagogy.

As Seron and Silbey have so clearly shown, reform and self-study efforts in engineering education are habitually inhibited by the instrumental and inward-facing professional character of the discipline. The inculcation of discretionary habits in engineering students faces notable challenges as even the most innovative programs customarily seek to systematize and thereby legitimize their instructional techniques.¹⁰ We may build on their findings to probe the ways in which outcomes-focused instruction discourages open societal or ethical inquiry about the origins and impacts of engineering in the ABET-compliant classroom today. In so doing, we may begin to add depth and complexity to existing efforts to enact democratic aims in engineering education, including studies of how Criterion 3 has thus far achieved such aims.^{1,2,11}

Outcomes, Assessment, and the Limits of Open Inquiry

As summarized by Besterfield-Sacre and Shuman, in the early 1990s ABET leaders began to perceive instructional priorities lingering from the Cold War era, closely focused on firmly pre-set course content and student acquisition of that knowledge, as outdated. The idea of an

engineering pedagogy more responsive to shifting commercial and geopolitical conditions emerged, along with hopes for curricula that might integrate technical and non-technical content to thus offer "more than technical" capacities to graduates. The perceived necessity of transferring engineering "knowledge, skills and values to new situations" as the century closed was seen to call for a shift from emphasis on "what is taught" in the American engineering program to "what is learned," and the organization's new, outcomes-focused accreditation criteria came into being.⁷

While a certain creativity and mobility on instructors' and students' parts is implied in that reorientation, the centralized character of the accreditation system rendered the new approach in some ways as ideologically inflexible as previous quantitative, input-focused systems. In articulating outcomes to be attained by American engineering programs, ABET has instituted a system in which assessment and feedback play an all-powerful role. For participating departments, success is predicated on predefined ideas of what categories of concern should be included in engineering coursework. ABET's general "Student Outcomes" are augmented by slightly more specific "Program Criteria" outlining discipline specific content to be mastered (for instance, students must be able to "apply calculus based mathematics..." and "conduct civil engineering experiments..." in any "Civil Engineering or Similarly Named Programs").⁴ Individual departments commonly lay out their own "Learning Objectives," to articulate still more specific means of meeting these criteria. Instructors, in turn, embed objectives into syllabi, course materials, and exams, thus assuring that particular content will reach the eyes, if not the minds, of students. At first glance, this set of nested expectations and tasks simply seems like a functional requirement for any shared educational effort that is not to devolve into chaos. But that presumption, favoring an "inventory" approach to teaching and learning, while maximally efficient in a certain sense also forecloses open-ended inquiry in the classroom, and thereby at least to some degree disciplinary reflexivity and a critical political sensibility about the origins and impacts of engineering. "Success" at each level is seen to reflect effective practice at the level above; both good and bad results are cast as sources of feedback to optimize instruction.^{10,11} The subtlety with which such planned, standards-focused pedagogy limits critical reflection (about both the pedagogy and the discipline writ large) is striking.

There is a circularity inherent at many points in the process. For example, in making recommendations for how engineering departments might effectively enact ABET criteria, one pair of chemical engineering instructors (sharing their findings in a journal for engineering educators), writes that, "...the measurement of student achievements in the courses should provide considerable information on the curricular effectiveness of an academic program."⁹ Also very common is the idea that a failing student should repeat the failed class, a concept to which we will return but one which for the moment can be seen to serve a kind of closed logic about what constitutes effective pedagogy. "Successful" alumni and employers are brought into assessment processes to complement instructors' efforts, further limiting the possibility that unprecedented content or radical outlooks might be introduced into engineering curricula. The pressure on educators seeking accreditation to demonstrate student attainment, and thereby to "tick boxes" for auditors, is tremendous from within their own institutions and this may encourage not just a pedagogical conformity to audience expectations, as Seron and Silbey have found,¹⁰ but also encourage a kind of administrative conservatism. For example, some instructors stress that effective long-term assessment depends on providing students with

material of consistent difficulty from year to year. Others suggest that formulating assessment protocols may appear burdensome to faculty at first, but any instruments developed for this purpose may then be re-used in subsequent years, relieving that burden.^{1,11}

Most broadly, the absence of political and social justice concerns in much of the routine discourse of engineering (as expressed in the discipline's syllabi, textbooks, exercises, etc.)¹³ makes it very unlikely that such content will find its way into assessment criteria, despite the appearance of such priorities in ABET Criterion 3. For many engineering educators, surveys, spreadsheets, and profoundly complex statistical analyses are seen to assure careful and accurate assessment of instruction.^{2,11} But however meticulous or detailed such instruments may become they nonetheless assure the circularity of any assessment processes predicated on predetermined plans. Again, this predetermination may seem like a foundational element of *any* quality-control process (whether educational or otherwise), but it nonetheless helps limit the possibility that new ideas critical of existing engineering practices will be expressed in classrooms, by either instructors or students.

Constructing the Uncritical Student

We can thus see how cultural ideologies and administrative practices reinforce one another in engineering (certainly also true in every other professional arena). But for the fullest understanding of these predilections in engineering we must also consider how the profession exerts such limits on reflexivity through the accreditation system itself. As one analysis of ABET methods offered (approvingly), "[ital in original]...*student learning outcomes are observable and measurable applications of applied knowledge*."¹⁴ Evidently, that which is not measurable or observable is not valued (a tenet of engineering beautifully interrogated by Seron and Silbey for its educational implications¹⁰); but surely we can also agree that political and ethical sensibilities are qualities that are neither measurable nor observable in any simple sense. Shuman, Besterfield-Sacre and McGourty have carefully articulated the potential of new, more complex assessment tools (such as open-ended student interviews or portfolios) to enrich teaching and learning in engineering, while expressing concern that the cost in time and resources such tools require might unfortunately limit their use.² But we might take their important findings one step further: the complexity of assessment tools will only introduce epistemological (and thus, political) openness into assessment if the rubrics in use are themselves rigorously critiqued from a political standpoint. Not only do we need to offer students the possibility of rejecting the proposed engineering activity altogether in certain circumstances (asking, say: "Is this new hydroelectric dam actually needed? Could habits of energy conservation not provide a more socially equitable or environmentally sustainable option?"), but we must also empower disciplinary reflexivity ("In whose interest is this technical knowledge formulated or deployed? What do engineers gain by pursuing or using this knowledge?") .

If pluralistic and democratic engineering practice is truly our intention, we must think with particular care about the experiences of engineering students in this system. Subordinate in almost every respect to the other actors we have mentioned, the student stands to gain the least from challenging prevailing standards of pedagogical attainment. As things stand, the circularity mentioned above is actually reinforced, and students disempowered, when student feedback is incorporated into assessment processes. Students are customarily asked to evaluate courses on

the basis of how certain, predetermined learning outcomes were fulfilled, in their view. This is a very different matter than empowering students to raise new matters that may have been left out of the coursework. Significantly, from the viewpoint of a historian or sociologist of engineering perhaps, one such "missing" matter, resulting from the compartmentalizing of "technical" and "professional" content in engineering, is consideration of the social and political values that have led to existing epistemic choices in engineering.

I have found a few cases where the published learning objectives of engineering departments direct students to "develop a sense of responsibility and appreciation for the continuous well being" of the student's program,¹⁵ and the role of enculturation in engineering education is of course one of tremendous historical significance, especially regarding matters of equity in race, gender, sexual identity, physical ability and age.^{16, 17, 18} But more subtle, perhaps, are invocations of "professional" attainment or conduct in descriptions of engineering coursework. These may exert a fearful influence on students. Such invocations make existing curricula or course materials appear to students to be the only legitimate ones, and sweepingly associate existing curricula with life goals such as "skills necessary to functioning in society."¹ The student's stake in preserving existing disciplinary goals and attendant institutional structures is thus assured.

Contingency and Power in the Engineering Curriculum

Without attempting to paint a panoramic picture of engineering compared to other fields of intellectual endeavor, we can articulate the ways in which engineering epistemologies make it particularly difficult to interrogate matters of social and political power. Most obviously, engineering identifies itself with an almost extreme practicality. In a lengthy (and in certain ways quite nuanced) 2009 report for the Carnegie Foundation on recent engineering education reforms, Sheppard *et al* repeatedly have recourse to the belief that engineering is above all an instrumental pursuit (rather than one of open-ended or reflexive character): "Engineering practice is, in its essence, problem solving."¹⁹ Other authors formulate the idea that in accomplished engineering practice, "knowing must be matched by doing."¹⁴ Such instrumentality systematically displaces attention from the actors involved: those who bring about engineering (engineers and their patrons and clients) and those who live with its benefits (material comfort and well-being, profit, lucrative and secure employment, etc) and costs (to health, safety, national and personal security, labor conditions, etc). Pawley, Riley, and Nieusma and Riley helpfully articulate this absence, this evacuation of positionality, with close attention to the content of engineering education.^{13,17,20}

As mentioned earlier, the lack of specificity in ABET's A-K--what exactly would constitute "economic, environmental, social political, ethical, health and safety" constraints?--explicitly derives from an impulse to let individual sub-disciplines and departments dictate their own standards for these categories. And obviously, sustainability in nuclear engineering and in bioengineering, say, can be meaningfully specified in very different terms. Yet nowhere do the ABET outcomes articulate any sort of process for following the work of engineers upstream or downstream, or even a concern with differential power and influence. A stress on "teamwork," "communication" and even "multicultural" interests, as found in many prescriptive texts, may encourage consensus, but partly by so doing that emphasis deflects students from interrogating difference or fairness. For example, some educators equate "functioning on multidisciplinary

teams" with working well with business and management representatives, hardly a recipe for diverse political or social outlooks in an engineering project.² Nor is "sending kids to the Web," as one educator suggested as a partial fulfillment of outcome J ("a knowledge of contemporary issues") likely to introduce a critical sensibility into the engineering classroom.¹²

Also worrying are increasingly frequent invocations of "global" conditions in the literature of engineering education that evacuate any mention of deeply undemocratic commercial and labor interests supported by those emergent neoliberal systems. Globalization is often treated in these texts as a phenomenon exogenous to engineering, much as pollution, ill health, plunging global wage structures, and similar results of global industrialization are treated in documents such as the NAE's "Grand Challenges." Globalization regrettably is cast in such renderings as a sea change with which engineering must contend, not the result of engineers' own choices.^{19,21,22,23} When engineering educators advocate for "real world" or "problem based learning" and fail to expose these troubling structures of economic privilege and geopolitical influence, they foreclose authentic understanding of social and ethical features of engineering.²

Conclusion

It is tempting to return to a deterministic framework in trying to understand the social import of ABET's A-K outcomes. As a profession dictates its own best practices, it creates a set of demands that individual institutions and practitioners must follow to achieve success. Schools need accreditation to survive. STEM faculty, for their part, rarely gain tenure or research funding when they depart dramatically from prevailing research priorities. Aspiring practitioners (students) do themselves no favors when they question the priorities of those granting them an exam grade or degree. Similarly, job applicants will find no joy in questioning the ethical validity of prospective employers' wage practices or the sustainability of their products. But that simple "trickle down" story does not provide us with many usable lessons. How do such values arise in the first place? How might they be altered, in the face of entrenched and patently inequitable global economic relations today? Simple indictments of industrial capitalism are neither realistic nor satisfying; hoping that engineering and the economic systems that sustain it will "go away" will not suffice nor would we wish to live without their benefits.

On the other hand, we can begin perhaps by exposing gaps in the logic by which engineering currently claims to engage with democratic values. For example, to me it seems naive to suggest that the "professional" skills promoted in ABET Criterion 3 add value to American engineering graduates on the global market place, a labor market with growing pools of non-US engineers willing to work for lower wages. Such logic holds that if American engineering students immerse themselves in social and political understanding, they will stand out as more desirable employees than those from other nations who do not possess such familiarity; the ideas here is that "price isn't the only determinant by which engineers are hired."² This presumes, however, that one can inject values (a concern with ethics, or with sustainability, for example) where no such priorities are yet in place (as in the case of the employers with whom non-U.S. engineers are finding jobs).

What is more, we might acknowledge that U.S. firms and institutions do not normally celebrate the engineer who wants to talk about power, or labor relations, or environmental justice. The global market has devalued political and humanistic thought in technical work, but not least because professional U.S. engineering has long compartmentalized such matters itself. In his incisive critique of North American technocratic impulses, Darin Barney points out that oppositionality is difficult in places where engineering is undertaken because technical practice both depends upon and produces a sense of "utility and apparent necessity" regarding its projects.³ That seems to me to be a fair characterization of how engineering would approach the sturdiness of a bridge, the efficacy of synthetic skin for burn victims, or the efficiency of a microchip assembly plant. Some engineering projects support social justice, others reassert inequitable distributions of social power and privilege, but Barney frames the veneration of fixity in technical work as itself an obstacle to political action. Politics, he writes, depends upon the embrace of uncertainty and risk:

Political action relates to contingency not only as a beginning whose end is uncertain, but as something new that interrupts the certainty of prevailing conditions.

Technological enterprises, especially those focused on commercial innovation and global competition, instead reproduce:

...people prepared to secure themselves, and all of us, against the risks of unpredictable and precarious futures.³

Such conditions for technological participation, predicated on the attainment of consensus and continuity, seem likely to produce very narrow definitions of the environmental, social, political, ethical, and health and safety constraints to be shared with the engineering learner via Criterion 3.

The distance between understandings of social and political matters of that kind exhibited by engineering educators, and those evinced in many social-scientific studies of engineering, are nothing less than extreme. In part, this reflects that much larger cultural habit in the United States and other industrialized settings to treat technical and humanistic expertise as distinct epistemic projects. The social scientist and engineer assuredly will not get tenure by publishing in "one another's" journals. This distinction is evident in the wording of A-K and throughout the literature on applications of ABET's criteria: one engineering educator characterizes the student outcome regarding "knowledge of contemporary issues" as a "straightforward reference to knowledge acquisition."¹⁴ Another writes summarily that "ethics and global awareness" are matters "not related to engineering computation."¹¹ But this is a set of distinctions that social scientists and a small number of engineers have been analyzing and attempting to dismantle for the last forty years. Historians of science and engineering, sociologists, and scholars in engineering studies have understood for some time that values pervade science and engineering to no less a degree than they shape humanistic fields, and the claim of value neutrality by STEM disciplines is itself a means of deflecting attention from the cultural and social privileges of those fields.

Finally, in many discussions of how best to educate the professional American engineer of the 21st century, analysts approach this challenging prospect with the perhaps understandable goal of breaking down the work of engineering into constituent parts. Sheppard *et al*, for example, have formulated a chart of the "Types of Knowledge Used by Engineers." Here "theoretical tools" such as mathematical methods, "fundamental design concepts," "quantitative data,"

"process-facilitating strategies" such as those used for project management, and "contextual and normative knowledge" ("knowledge of values...personal, professional, cultural...") are disaggregated.¹⁹ But for many years now, historians and sociologists of science and engineering have shown how even apparently practical or empirical activities (calculation, measurement, the most mundane moments of technical design and fabrication) are steeped in subjective judgments. Similarly, no cultural norm (say, a drive for clean energy) takes shape if the practical means of executing it are not somehow imaginable (the mass production of solar panels) and economic imperatives do not encourage it (profitable mass production of solar panels). Disciplinary and cultural consensus about which projects or knowledge matters--a collectivity often based on social privilege--routinely keeps entire kinds of thinking on or off the engineer's table, a legitimizing process hidden in such schematic efforts as this chart. Invocations of Bloom's Taxonomy in many discussions of ABET Learning Outcomes function similarly to efface the social character of technical thought.¹⁴ To disaggregate these types of knowledge not only hides the complexity of engineering, but the ideologies informing engineering at every turn. It is these ideologies we need to explore if we wish to inculcate authentic social understanding through engineering education.

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