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# The dialectic between expert knowledge and professional discretion: accreditation, social control and the limits of instrumental logic

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Cycles of reform have been a constant feature of engineering education. This study suggests that these cycles are endemic because engineering begins with a particularly instrumental conception of responsible preparation. The instrumental logic of engineering repeatedly undermines educational reforms seeking to cultivate the capacities for discretionary interpretation and judgment at the root of professional practice. Using interviews with faculty at two new engineering colleges in the United States, we show how this instrumental logic once again leads to retreat from educational reform. Beginning with criticisms of engineering's failure to produce innovative and socially responsible engineers, new engineering schools attempted to address directly the limitations of instrumental rationality by creating curricula that would immerse students from the very outset of their engineering education in the ambiguous work of client-defined problem-solving. Rather than begin with the expertise grounded in mathematics and science and then teach how to apply that knowledge through known techniques, both programs asked students to become inquirers seeking knowledge, rather than implementers applying knowledge. As the programs sought legitimacy for their innovations through professional accreditation, however, the open-ended, exploratory processes of serendipitous learning were instrumentalized into a set of measurable procedures for acquiring standard, scientific expertise as the essential credential of the responsible engineer.

**Keywords:** engineering education; cycles of reform; instrumental logic; professional practice; discretionary judgment; accreditation

## Introduction

Shortly after the EC2000 revision of ABET accreditation procedures in the United States,[1] the National Academy of Engineering announced its ambition 'to reengineer engineering education.'[2] This latest call for educational reform is by no means a new story in engineering. As one historian of the field notes, 'Engineering education has been the subject of more studies and reviews, formal and informal, than any other

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[1]ABET, Inc., http://www.abet.org/history.shtml (accessed March 11, 2009).

[2]National Academy of Engineering, *Educating the Engineer of 2020*, 2005, pp. 18–19.

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domain of professional education.'[3] Whether in the aftermath of the industrial revolution, World War II, the Cold War, or today's nanotechnology explosion, environmental crisis, and globalization, the reform conversation has been regularly repeated. In each cycle, discussion focuses on the same 'basic issues ... including the relationship between theory and practice, the length of engineering education, and the nature and structure of general education courses.'[4]

We enter this ongoing discussion by examining closely two new engineering programs with innovative curricula designed to encourage and develop engineers' discretionary judgment, the very thing that has repeatedly been deemed lacking in each new cycle of engineering education reform. Smith College's Picker Engineering Program, founded in 2000, relies on its location within a highly selective college for women to provide the critical engagement and open inquiry characteristic of the liberal arts as a moderating influence on engineering's historic instrumentalism. The brand new Franklin L. Olin College of Engineering admitted its first graduating class in 2002, following an articulated mission to create a 'renaissance engineer' who would be simultaneously entrepreneur, scientist, and artist. This triangulated vision was implemented in a self-designed organizational structure, free of the traditional constraints of disciplinary and departmental divisions.

From their inceptions, both Smith and Olin made the decision to secure accreditation through ABET, Inc., the accrediting body for 'applied science, computing, engineering, and technology education' in the United States.[5] The EC2000 ABET criteria emphasize assessment of program outcomes rather than as in the past providing a list of courses that must be completed. The outcomes are assessed in terms of eleven criteria that programs must meet to secure accreditation.[6] Schools are also encouraged to develop additional measures (or criteria) for outcomes specific to their mission and goals. Because the new ABET criteria assess outcomes rather than particular course completion, programs are free to meet both the required and individualized criteria in any way they choose. However, to secure accreditation, all programs must demonstrate that they have a local 'assessment and evaluation process that periodically documents and demonstrates the degree to which program outcomes are attained.'[7] With an emphasis on outcomes, the new

[3]Seeley, "Patterns in the History of Engineering Education Reform," 2005, p. 114. Also see Seely, "The Other Re-engineering of Engineering Education," 1999; Downey and Lucena, "Knowledge and Professional Identity in Engineering," 2004.
[4]Seeley, "Patterns in the History of Engineering Education Reform," 2005, p. 115.
[5]ABET, Inc., http://www.abet.org/ mission.shtml (accessed March 11, 2009).
[6]Criteria for Accrediting Engineering Programs: 2009–2010, ABET, Inc. Baltimore Md., November 1, 2008, include (a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; (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; (d) an ability to function on multidisciplinary teams; (e) an ability to identify, formulate, and solve engineering problems; (f) an understanding of professional and ethical responsibility; (g) an ability to communicate effectively; (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; (i) a recognition of the need for, and an ability to engage in life-long learning; (j) a knowledge of contemporary issues; (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
[7]ABET, *Criteria for Accrediting Engineering Programs*, 2008, p. 2.



accreditation process is designed to encourage institutional innovations in how technical knowledge and discretionary judgment are delivered to students.

Rather than a standardized, top-down approach, the new assessment process and general outcome criteria allow programs, in theory, to take more individualized approaches in professional education. A close reading of the new ABET criteria suggests, however, that although the process has been loosened to permit more flexibility in engineering programs, it remains an official audit with all that auditing entails. Whereas the old ABET criteria openly encouraged a process of 'bean counting' to make sure that a program met required standards, evidence suggests that the new accreditation process may have shifted little, requiring each institution to put in place its own assessment process while encouraging each local institution to designate which beans will be counted and assessed. Despite an overall goal to encourage innovation in engineering education, the new criteria for accreditation may once again reproduce engineering's traditional instrumental educational emphasis.

We begin with the premise that engineering finds itself in nearly continual debate about how to educate a different and better kind of engineer because it relies on a particularly instrumental, narrowly conceived conception of professional responsibility; this instrumental orientation has self-defeating consequences for the scope, creativity, and flexibility of engineering education. This instrumental orientation is not surprising as engineering is centrally about the meticulous operationalization and instrumentation of scientific knowledge to solve material and behavioral problems. Engineering is often conceptually distinguished from basic science 'oriented to the production and evaluation of knowledge claims,'[8] by its focus on application and client initiated problem solving. Whether described as applied science, 'the discovery of new uses of knowledge claims previously evaluated and tentatively accepted' or in terms of its orientation 'to the solution of technical problems where the problem to be solved is regarded as given,'[9] engineering is about turning knowledge into procedural recipes for physical and human action.[10]

When confronted with the task of designing the education of engineers, the profession has diagnosed and implemented solutions through the same epistemological and cognitive lenses honed on matter, machines, and systems. Engineering has historically demonstrated abhorrence for what are often called Type II errors, that is, ignoring or failing to recognize an important condition or variable.[11] Like the medical profession, engineering has preferred to make errors of over-diagnosis or over-specification, that is, preferring to act rather than wait to see what happens. This is a reasonable interpretation of the profession's obligation to provide safe, reliable solutions for client-defined problems. With responsibility to reduce the risks associated with technological systems, professional engineers conventionally build in multiple fail-safe mechanisms where risk cannot be eliminated. Thus, inventing technologies is a process of specifying clear links between thoroughly identified

[8]Cohen, *Developing Sociological Knowledge*, 1989, p. 52.
[9]Cohen, *Developing Sociological Knowledge*, 1989, p. 52.
[10]Of course, engineering is not merely applied science but has, since the 19th century, developed independent theory and methodologies characteristic of engineering science.
[11]In statistics, the term Type I error names the decision where a true situation has been rejected as false; Type II error names the decision where an untrue situation has been accepted as true. See Moore, *Statistics*, 1979.

components that seem, at the moment, to reduce uncertainty and risk.[12] These orienting professional obligations produce a professional ethos where empirical reality is represented entirely through the procedures used to measure it, eschewing as unscientific or bad engineering that which is not measured or measurable. Importantly, the scientism of engineering derives less from the scientific content of much engineering education than from the presumption that all problems can be reduced to physical science and removed from the context in which they are embedded.

And yet despite efforts to reduce uncertainty and risk, because professional practice relies on expert knowledge that is deployed in discretionary[13] situations with clients, that practice is inherently indeterminate. Client service is, after all, the raison d'etre of the profession; therefore, engineers cannot avoid applying their knowledge in circumstances not entirely known or measured by existing knowledge. This tension has been historically mediated through a combination of legal and organizational processes serving the interests of both clients and practitioners to secure reliable performance: accreditation of educators by professional associations, certification and licensing of practitioners by state agencies, and investigation of claims of malpractice. The weight has been put, primarily, on efforts to specify the corpus of expert knowledge through accreditation of training rather than dealing with the uncertainties of practice.

The cycles of education reform emerge directly from this preference for over specification and reduction of discretionary judgment. Rather than recognize the dialectical relationship between expertise and discretion as mutually dependent, reform of engineering education responds to each initiative calling for more breadth and liberal education with specific behavioral requirements. Each new set of accreditation or licensing requirements identifies heretofore unperceived phenomena that are discovered and recognized as playing a role in technological systems and essential for professional engineering practice. New courses or subjects not yet included in the standard engineering curriculum are recommended for inclusion. Once identified and named, however, engineering faculty and accreditation boards specify the new requirements in meticulous detail in order to assure compliance. The critique that called for change and identified the missing element – whatever it may be in that reform cycle – slips away as it becomes operationalized as a set of measurable training requirements. Within a few years, dissatisfaction with the newer curriculum requirements generates yet another set of reforms. As economic and social changes outpace the reformed curricula, new amendments are recommended to capture evolving technical knowledge and the yet elusive practical and interpretive skills of the professional engineer. Thus, over the twentieth century, engineering education has reached beyond math, physics, and mechanics to include the study of human factors; human factors work led to a focus on aggregated human action in organizations and the study of management; the study of human factors, organizations and management led to a focus on technological systems, and most recently, engineering education reforms call for reexamining the balance between the

[12]Conventionally, hazards are unwanted events, risk is the probability of the occurrence of a hazard, and uncertainty refers to those situations in which probabilities are unknown or cannot be assigned.

[13]Davis, in *Discretionary Justice*, 1969, defines discretion as unreviewed decision-making.



theory (science) and practice (design) with particular attention to ethics, values and social responsibility writ large.

In the following sections, we report how faculty at two new engineering programs attempt to overcome cyclical patterns of reform. We show that faculty at Smith and Olin begin with deep criticisms of the profession's instrumental logic and its failure to produce innovative and socially responsible engineers; in response to these criticisms faculty at these new schools designed curricula to immerse students in the ambiguous and uncertain work of client-defined problem-solving from the very outset of their engineering education. Rather than begin with presumed certain and sure science[14] and then teach how to apply that knowledge through mastered techniques, both programs asked students to become inquirers seeking knowledge rather than implementers applying knowledge. Smith and Olin also sought accreditation from ABET, Inc. Because accreditation secures occupational legitimacy, authority, and marketability, each school's aspirations to produce a new kind of engineer were enacted, and then transformed and confined within the more conventional expectations and procedures of the credentialing process. As the programs sought legitimacy for their innovations through professional accreditation, open-ended, exploratory processes and serendipitous learning were instrumentalized into a set of specified, measurable procedures. We suggest that these notable innovations are unintentionally constrained by engineering's history as well as their own professional biographies. We elaborate these and other themes that emerge from our interviews in the conclusion.

## Research methods

How do the engineering faculty at Smith and Olin manage competing interests in professional accreditation and professional innovation? How do they balance demands for technical expertise and discretionary judgment? We explored these questions through a series of open-ended, semi-structured interviews conducted with faculty at Smith and Olin between 2003 and 2004. Each interview was conducted at the faculty's home institution, usually in his or her office. Interviews lasted from 60 to 120 min, with an average length of 90 minutes. We interviewed seven engineering faculty at Smith in 2003–2004, in addition to key administrators in the College. We also interviewed sixteen faculty and administrators at Olin.

We asked about a wide range of topics, from professional background and research interests to decisions to enter engineering and the professoriate. For the purposes of this analysis, we draw upon questions that invited faculty to discuss the mission and pedagogy at their respective programs. All interviews were transcribed and coded using both inductive codes and concepts from the existing literature.[15] The goal of the analysis was to specify the ways in which the faculty designed the curriculum, developed pedagogy, and managed the accreditation process. Importantly, we wanted to understand how the faculty interpreted the current needs of the profession and the strategies of their institution's program in addressing

[14]For a survey of the rich literature challenging the notions of certain and sure science, see Collins and Pinch, *The Golem*, 1998; Bijker et al., *The Social Construction of Technological Systems*, 1987; Biagioli, *The Science Studies Reader*, 1999; and Jasanoff et al., *The Handbook of Science and Technology Studies*, 1995.

[15]Glaser and Strauss, *The Discovery of Grounded Theory*, 1967.

those needs. We wanted to identify analytic and conceptual themes concerning the paradoxes and tensions of professional education. In interpreting these findings, it is important to note that we report on what faculty say and believe. Because we rely on interviews only in this paper,[16] what the faculty say represents and constitutes not necessarily accurate reports of what is done, but rather the cultural materials with which they work and make sense of their work.

## Operationalizing innovation

Modern professionalism is a balancing act between certification of technical, expert knowledge, and discretionary, hands-on judgment in service to clients. Thus, professional education must impart to students a body of formally collated, often abstract knowledge that constitutes the domain of expertise while recognizing that the real world problems that clients present may not fit textbook descriptions and therefore require judgment and art that cannot be secured by licensing exams testing that formal knowledge. Every application of formal or technical knowledge to an empirical situation is therefore an interpretive act, fraught with ambiguity, calling for discretionary judgment. In contrast to the conventional liberal arts, for example, professional education seeks an amalgam of book-learning in class with hands-on training through practice and experience. The difficulties of achieving a stable fusion of theory and practice is exacerbated by the fact that formal knowledge is by definition abstract; practice with a client is technical, yet quintessentially social; and knowledge and practice are different, yet the boundaries are ambiguous.[17] Thus, rather than mastering specific techniques or collections of facts, the fundamental challenge of professional education is to develop the capacities for judgment: artful 'diagnosis, inference, and treatment.'[18]

Although the emphases are slightly different, both the Picker Program at Smith and the Olin College of Engineering actively seek to build a functioning bridge between the classroom and the world of professional practice beginning in the very first year. This contrasts with more traditional engineering programs that require an introductory year of basic science as a foundation for subsequent engineering courses. In addition to a rigorous engineering-focused curriculum, first year students at Smith and Olin participate in design competitions to meet client product needs. Pedagogically, each site approaches the socialization and education of new students by immediately integrating practice and theory, i.e., by demanding that first semester students get their '*hands dirty*'[19] working with a client on an engineering project, and then figuring out why it worked, or did not work, through close analysis of the mathematical, physical, engineering, and organizational problems they confronted. Both programs seek to build from the assumption that the ambiguities and indeterminacies generated by designing artifacts before fully understanding the mechanisms is essential for the cultivation of professional judgment. The steps taken

[16]Although the interview data were rich and detailed, the analysis is nonetheless limited by the use of interview data only, and in future research will be supplemented with data from classroom observations and student interviews and surveys.
[17]Abbott, *The System of Professions*, 1988, pp. 8-9 and p. 20, Freidson, *Professional Powers*, 1986; Dingwall, "Professions and Social Order in a Global Society," 1999; Hughes, "Dilemmas and Contradictions of Status," 1945; Dryburgh, "Work Hard, Play Hard," 1999.
[18]Abbott, *The System of Professions*, 1988, p. 40; emphasis added.
[19]All excerpts from faculty interviews are italicized.



by Smith and Olin are designed to integrate learning technical expertise and discretionary decision-making from the start.

To represent the emergent engineering culture at Smith and Olin, we analyzed our interviews with the faculty at Smith and Olin through four dimensions that are fundamental to social structure. Table 1 provides a summary of the data along these dimensions or processes: (1) normativity, or how an organization defines its mission and goals, (2) capacity, or the means deployed to achieve those goals, (3) constraints, or institutional factors that may impede achievement of goals, (4) time and space, or the temporal and spatial ordering of social activities.[20]

Both Smith and Olin attempted to bridge the space between expert knowledge and professional discretion. They defined their missions differently and enacted them with very different organizational opportunities and capacities. Yet both new schools found themselves adjusting and moderating their ambitions to fit within the audit instruments required to achieve legitimacy and status as professional engineering institutions. We begin with a consideration of Smith's program and then turn to a discussion of Olin.

## *A liberally educated engineer at Smith College*

### *Normativity, organizational goals, and mission*

In 2000, Smith College, one of the few remaining women-only, highly selective liberal arts colleges in the country, created the Picker Engineering Program and introduced a B.S. degree in engineering, specifically to enhance the presence of women in engineering. Drawing confidence from Smith's historic success producing women leaders with a commitment to social service in diverse occupations and professions, the Picker program focuses on engineering as a liberal art and as a profession in service to humanity.[21] The Picker program consists of an integrated set of courses that builds on existing programs in the basic sciences and humanities. The B.S. degree in engineering is the first technical undergraduate degree ever offered at Smith. At its core, the engineering program relies on the liberal arts environment as a primary resource for developing students' capacities for critical thinking, ethical deliberation, and responsible judgment. By more fully integrating communication and abstract reasoning skills with inquiry into the human condition, Smith hopes to 'redefine traditional engineering education,' to educate a socially responsible engineer. The Smith program seeks to integrate theory and practice. Smith's website announces that 'we believe that women engineers should think deeply and broadly about the effect their professional knowledge will have on the well-being of those whose trust they hold.'[22]

Echoing its fundamental goal to educate women engineers, by 2008 fifty percent of the new engineering faculty at Smith were women, slightly lower than the traditional gender representation among its science faculty. The fact of gender parity among the faculty, some think, offers the strongest support for Smith's ambitions to produce successful women engineers. 'Women's colleges hold the edge over co-ed

[20]Ewick and Silbey, "Subversive Stories and Hegemonic Tales," 1995; Ewick and Silbey, *The Common Place of Law*, 1998.
[21]http://www.science.smith.edu/departments/Engin/ (accessed February 21, 2009).
[22]http://www.science.smith.edu/departments/Engin/ (accessed March 11, 2009).

Table 1. Organizational and curricular comparison of Smith and Olin.

| | Smith College, Picker Program in Engineering | Franklin W. Olin College of Engineering |
|---|---|---|
| Normativity: Organizational goals, mission | Social responsibility, critical thinking, leadership | Renaissance engineer: Entrepreneur, scientist, artist |
| Capacity: Means to achieve goals | Liberal Arts college: 'Latin Honors:' engineering courses 'integrated' into liberal arts and basic science curriculum | Non-departmental organization; participatory governance<br>'Gates:' end of year exam. week-long, institution-wide assessment, includes written and oral exams, team exercises |
| | (1) *Introductory courses* in Math and Physics Departments | (1) *Foundation: (a)* cohort course – interdisciplinary in basic math & physics in a project design<br>(b) sophomore design project |
| | (2) '*Engineering for Everyone*' | (2) *Specialization and Realization:* (yrs. 3&4) courses in different areas of engineering application with links for corporate involvement; international study encouraged |
| | (3) *Nine 'core' engineering courses* selected from mechanics, electrical systems and thermochemical processes | (3) *Capstone project simulating professional practice* |
| | (4) *Upper division*: Three courses in technical concentration, designed in consultation with advisor | (4) *Culminating project in humanities* |
| | (5) *Design Clinic*: Seniors work in teams to three to four under supervision of faculty and corporate liaison/sponsor | (5) Encouraged, but not required, to take *Fundamentals of Engineering* exam, designed by Olin Faculty |

(*continued*)

Table 1. (*Continued*).

| | Smith College, Picker Program in Engineering | Franklin W. Olin College of Engineering |
|---|---|---|
| Constraints | B.S. degree requirements, breadth and depth<br>Accreditation: -signal rigor and differentiate from lack of rigor in liberal arts; -signal rigor and challenge stereotypes of women as soft | Degree debates: One degree or three<br>Accreditation: -seek professional legitimacy for new institution without reputation; -ambivalence about type of engineering degree |
| Temporal Ordering | How to fit rigorous program within the liberal arts BS degree; Where is time for faculty to invent and students to take synthetic exploratory courses; How much science can be built in. Accreditation took time; satisfying | Faculty inventing curriculum; Interdisciplinarity; Collective governance |
| Organizational/ Spatial Frame | Selective, liberal arts college<br>Single-sex<br>Highly selective<br>Residential | *Tabula rasa*<br>"New" site<br>Highly selective<br>Residential |

schools' in producing women scientists, educators say, not simply because of the composition of the student body but because there are also more women on the faculty, serving as mentors and role models.[23]

Smith also embodies its commitment to excellence and diversity through its energetic recruitment of minority students and generous aid packages to insure that no structural barriers impede students' education and development. By changing who becomes an engineer, while broadening engineering education to be a liberal art, the Picker program hopes to graduate engineers who are agents of social change, students who are creative thinkers, yet see the big picture and recognize that engineering models are simplifications of reality that often leave out societal costs.

Throughout our interviews with faculty at Smith, they emphasized the normative commitments and distinctiveness of the program by comparing it to their own experiences as undergraduate students in engineering. Although each of the Smith faculty is a highly accomplished engineer, the words they selected to describe their undergraduate and professional preparation were quite negative, providing a contrasting and repugnant benchmark against which they evaluated Smith's commitments and variation from traditional engineering programs. For example, some described their undergraduate program as unnecessarily '*hard*' for its own sake, or as requiring a lot of memorization and regurgitation; and, they recall large, anomic lecture classes. Indeed, one faculty member went so far as to describe his undergraduate classes as analogous to a fraternity '*hazing*;' explaining:

> *The idea that we can offer a degree in engineering science ... that we can teach our classes in a way which is much more centered on the student, as opposed to being a lecture class. I think [that there is] a lot more [that] we can do, even in terms of developing a community of learners, as opposed to just having students be miserable in a hazing-type engineering program. [And,] we can look at issues of how women learn engineering, and actually try these things out.*

Compared to the culture of a traditional engineering program as recalled by these faculty, the Smith milieu encourages a degree of experimentation in both course content and pedagogy. Whatever the historical veracity and variation among their recollections, what is done at Smith is interpreted as completely different, and better.

### *Capacities, means to achieve goals*

The opportunities at Smith are rich for invention. The liberal arts culture encourages and takes for granted critical thinking, indeterminacy of knowledge, and moral ambiguity. It firmly embraces iconoclastic perspectives and the role of power in social relations, including knowledge-making. For example, Smith engineering faculty talk about using a '*feminist and radical pedagogy*,' of teaching '*critical thinking*,' of empowering students to take responsibility for their learning by asking questions, of getting rid of the '*military*' thinking that has historically dominated engineering education, putting an '*ethics*' component into every class, and understanding the role of the engineer '*inventor*' in a social context. One faculty member describes the capacity of Smith to encourage a different approach to engineering this way:

[23]Sebrechts, "Where Female Scientists Grow," 1999; Sebrechts, "Nurturing Scientists at Women's Colleges," 2000; Tidball, *Taking Women Seriously*, 1999.



> *Our curriculum is integrated with the liberal arts. We're producing students who have more communication skills, and more, more [of a] sense of the social impact of their work because of the way that we teach engineering in context; also, the pedagogy that we have [is] different; everybody has sort of a different philosophy. I do feminist pedagogy, and critical pedagogy, so I'm trying to give students responsibility for their own learning, and for teaching each other. And so I think that that, at least theoretically, it should be building confidence and enabling students to really come into their own as engineers, and that's the thing that is sort of the inverse of the way that a lot of us were taught engineering, which was, you know, do what we tell you to do, and it sort of models exactly what the ethical problems are for engineers in organizations where they follow orders in a certain military way.*

Every faculty member elaborated at length on the strengths of small classes and discussion seminars to encourage active learning through student participation.

The Smith engineering faculty recognizes that it is the college itself, and its liberal arts traditions, which allows them to experiment. Indeed, from the standpoint of the liberal arts culture, the new pedagogical strategies and epistemological orientations in engineering are, in fact, quite normal. Small liberal arts colleges pride themselves on seminar teaching formats in which students are regularly and consistently given the opportunity, and specifically taught, to develop their distinctive voices. Moreover, women's colleges, such as Smith, have been the source of a great deal of feminist scholarship identifying women's experiences and perspectives, including for example research on the status of women, the universality of gendering processes, or the differences among men's and women's ways of knowing. Teaching students to challenge orthodoxy, to uncover hegemony, to identify subversive narratives[24] is part of the common curriculum at self-defined feminist institutions. Even where feminism may be less prevalent, or even absent, teaching critical, self-reflexive thinking is the coin of the realm of a liberal education where there is an expectation that graduates will become professional and public leaders,[25] including those who will challenge orthodoxy.

As one Smith faculty member commented, the challenge and the excitement of being at a liberal arts college is to maintain an '*active dialogue with all faculty [across the college] who teach a course that is in any way related to engineering*.' For example, if one is teaching a course in mechanics, it would be important to teach the history of the idea of the mechanic, as well as the relevant engineering properties. It would also be important to explore the role of machines in transforming everyday life and the relationships of different groups and genders. The intriguing idea is to take the liberal arts tradition seriously and turn the whole subject matter of teaching mechanics on its head; the opportunities to be creative, innovative, and new – if not iconoclastic in one's teaching of engineering – are many.

### *Constraint*

Yet the liberal arts tradition of a small residential college is also a constraint. Conversations with faculty suggest that developing an innovative program is a high wire walk marked by opportunities to be innovative and a series of dilemmas that set limiting boundaries. The liberal arts tradition at Smith offers its engineering faculty, who come out of a very different professional culture and tradition, degrees of

[24]Ewick and Silbey, "Subversive Stories and Hegemonic Tales," 1995.
[25]Strauss, *Liberalism*, 1968.

freedom and resources in teaching engineering science. Yet engineering faculty describe clashes between the arts and social sciences faculty and the engineering faculty, between the soft humanities and the rigorous sciences, between critical humanities and conformist engineering, between social service and technical skill. For example, just as a liberal arts education assumes a large measure of contingent exploration, the culture of collegiality is guided by a commitment to decision making through what often seems like roundabout, indecisive, time-consuming consensus-building, and deliberation.[26] In contrast, engineering education is about preparing R&D professionals, who work in quite different settings, with minimal opportunity for unscripted exploration. Where the liberal arts faculty expects process and deliberation, the engineering faculty expects decision and faithful implementation.[27] Thus, it is not surprising that the Smith engineering faculty report that they felt that they were seen as '*arrogant*' and '*perhaps macho*,' driven, directed, and directing, in the Smith college milieu that, as one person put it, operates through '*a veneer of civility*.' In the long-term there will be ways, no doubt, in which the engineer's professional ethos will infiltrate Smith's more intellectual, critical culture. But, at the outset, it is clear that some of the practices and traditions of Smith do constrain the desired opportunities. Perhaps more than the arrival of the engineering faculty themselves, the Bachelor of Science (B.S.) degree symbolizes a different kind of educational commitment – one that is practical and professional, putting the engineering faculty in a position of '*having to prove*' themselves to their liberal arts and sciences colleagues to be taken seriously as scholar-teachers rather than as technicians.

Constraints on innovation are not limited to a generalized clash of cultures between engineering and liberal arts; in many respects, our conversations with faculty suggest that the ABET accreditation process, even with its emphasis on mission and outcome assessment, proved to be perhaps a more powerful constraint on innovation. The management of the accreditation process in year five[28] of the program exemplifies the mediation between professional and local institutional tensions through instrumental accommodations to more conventional curricular expectations. Even if the ABET audit no longer includes a checklist of requirements, (for example, where and in what sequence the curriculum delivers teaching about ethics and responsibility or electricity and magnetism), as it might have in the past, those expectations are there nonetheless.

Some interviewees mentioned that the mission-driven accreditation processes through which the institution identifies, names, and describes how it enacts its expectations, merely pushed the faculty to do what they wanted and needed to be doing anyway: sort out their mission and goals, figure out how to implement them through courses, sequence courses and assignments, and, finally, determine how the cumulative experience, including the final Design Clinic, prepares graduates to be effective, thoughtful, reflective, and responsible engineers. As one faculty member noted,

[26]Waters, "Collegiality, Bureaucratization, and Professionalization," 1989.
[27]Kunda, *Engineering Culture*, 1992; Vaughan, *Controlling Unlawful Organizational Behavior*, 1983; Vaughan, *The Challenger Launch Decision*, 1996.
[28]In 2005, ABET retroactively accredited Smith's program for the first graduating class of engineers in 2004.



> *You know, the focus on ethics, social responsibility, communication, all of those things are embedded in ABET as outcomes. And so, this is different from the way it used to be. [It] used to be bean-counting, like so many credits of this and this and this. And now it's very open, and we can design our curriculum to meet these goals.*

Nonetheless, many faculty expressed reservations about the ABET accreditation because they recognized and described how it inevitably becomes a process of fitting into someone else's agenda, even if that agenda has recently been made more capacious and pluralistic. Once inside the accreditation process, there was a high price to pay in the loss of freedom to innovate.

> *I think yeah, people do have some real questions about how has this cramped our style. What could we have done? And I think it's important to ask those [questions]. And at some point we may, you know, we may not pursue it. But I do think there's a great cost for this program, to not pursue accreditation …*

Some faculty also expressed a bit of envy toward programs that could afford by their historic status to ignore accreditation. As one faculty member noted,

> *Established programs don't always care about ABET. Like CalTech, I think, decided a few decades ago that they were going to do things their way, and they didn't care if ABET thought they were great or not because they're CalTech. So, for us, we don't have that luxury.*

And, since Smith faculty do not enjoy that '*luxury*,' they found themselves in the '*time sink*' of securing ABET accreditation. As inhibiting as a check-list of requirements might have been, it nonetheless would have focused attention, created limits, and established criteria of completion. Being much more open and emergent, the accreditation criteria were implicit rather than explicit, demanding even more faculty investment, and self-reflection. The preparation reached a point where, many reported, it simply became an arduous task to be completed in the most direct and efficient, instrumental manner possible. Reflecting on the faculty's concerns, one described it this way

> *And we're not sure how it's [i.e., the new outcomes assessment model of ABET] going to actually be applied. I think that's one of our concerns is that it really is different … I guess the only thing would be how much time should we put towards it and how seriously should we take it? Should we do it to the last degree? We know a lot of programs just do enough to get by. Should we do just enough to get by, or should we do a whole bunch more?*

Although faculty voiced reservations about the costs of its logic and work demands, there was unanimity about the importance of accreditation. To a person, there was a consensus that accreditation is a necessary step to ensure the '*legitimacy*' and '*credibility*' of the program in the wider engineering community. First, accreditation is necessary because the Picker Program is housed within a liberal arts college, and as a consequence, the engineering faculty needs to establish itself as appropriately rigorous. Unlike the liberal arts subjects and faculty, it is important that the engineering program and faculty not be viewed as '*soft*.' Elaborating, this faculty member explained: '***ABET is sort of our means of proving ourselves. So if we get accredited, that says to the engineering community that we're tough enough…***' Here the tension between certainty of knowledge and ambiguity of practice at the heart of the profession is repeatedly articulated in the interviews. Although Picker has been created to educate a different kind of engineer – one who is critical, socially responsible, and unlike the well-trained but poorly-educated conventional engineer – in describing the importance of the accreditation process, the engineering faculty consistently devalue and mock the liberal arts and its faculty in terms that reproduce the traditional divide between the two cultures.[29]

Second, faculty suggests that accreditation is necessary and important because Smith is a women's college, and as a women's institution, they do not want to be seen as teaching '*engineering-lite*.' Or, as one faculty member put it

> *I think as ... the first women's college to have an engineering program, and the only program that's all women, ... you worry that people are going to say, "Well, it's a women's program. It's not as good as the other ones." Or it's soft or something. And so for us it's important because this is a stamp of approval that our students currently meet the technical rigor of the field. So I think we find it to be very important [to be accredited].*

Thus gender, like the liberal arts, is a conventional mark of difference, an unwelcome status difference for engineers.

Third, accreditation is necessary, according to the faculty, because '*it is important for us to establish ourselves as a credible program; one of the best outside benchmarks for that is accreditation*.' Smith's program is founded on the premise that a liberal arts, women's college engenders the capacity to develop an innovative program. These same assets become, however, constraints in the context of accreditation. Hence, faculty suggest, there is a need to prove to the professional community at-large that the program is credible by the standard, taken-for-granted benchmarks of traditional engineering education.

Some faculty also suggested that moving too far afield of the traditional core threatened to compromise the support and legitimation of the key stakeholders, including industry and employers. One faculty member commented that the legitimacy and credibility of the degree depends, ultimately, not on what their ABET colleagues think of the Smith program but maybe more importantly on '*how industry views its graduates*.' Thus, in addition to ABETs control over the development of the Smith program, the marketplace will also act as an agent of control, this professor notes. Steps must be taken to ensure that Smith's graduates are good '*ambassadors*' for the program, that they bring the requisite skills to be '*doers of engineering*' so that they can achieve the program's goal to be leaders in the field.

*Time/Space*

If the spatial context of the Picker Engineering program is unconventional in its organizational home in a liberal arts college, the temporal configuration of the engineering curriculum at Smith looks a bit more 'traditional' than the program at Olin. Students are required to begin with basic courses in math and physics, as in most engineering programs, as well as an introductory course in engineering, which is open to all Smith students, not only those working toward an engineering degree. Nine additional courses across engineering fields fill out the degree requirements. Like most liberal arts degrees, engineering students also begin specialization as they

[29] Snow, *The Two Cultures and the Scientific Revolution*, 1959.



move into their junior year; for an engineering degree, a technical concentration is composed of three related courses (among the nine electives) that are selected in consultation with an advisor. The engineering curriculum is capped off with a senior design clinic. As the engineering faculty struggle to balance a Latin Honors core with rigorous courses in math and physics, followed by breadth and depth courses in engineering, with a design clinic as a culminating project, they must still play by the rules of the liberal arts B.A. degree. This means, for example, that one may take only a limited number of courses per semester so that students have time for contemplation and serendipitous inquiry; that students must complete a set of unspecified, free-choice electives; and that all of this must be done within a four-year time frame with standard vacations and summer recesses. The college's timetable and requirements for completing a B.A. degree are designed to provide opportunities for unprogrammed exploration, personal reflection, and unscripted learning, so that students are more likely to become self-learners with critical judgment. The degree assumes a large measure of indeterminacy and as such exercises – by its contrast – a powerful constraint on how the B.S. will be invented and implemented at Smith.

Picker faculty resolved perennial trade-offs between basic core requirements and exploratory inquiry in the direction of more conventional instrumental conceptions of engineering education that reduced opportunities for and commitments to their imagined, iconoclastic engineering classes. Faculty never questioned the role of the standard math and science core, which, inevitably, limited the time available for their imagined and hoped for multi-disciplinary approach. Because faculty hewed to the belief that students need to have rigorous preparation in math and physics, the bread and butter of engineering representations, analyses, and communication, there was less trenchant questioning of what constituted an appropriate core, and then little room in the curriculum for reframing the basics of engineering. Without abandoning the more imaginative conception of engineering, unscripted exploratory inquiry was relegated, as is common elsewhere, to the status of gravy on the basic meat.

In sum, as it attempts to institute an innovative program producing socially responsible engineering leaders, a program that challenges the conventional, supposedly failed model, the Picker faculty seems nonetheless to reproduce many of the values and preferences of the conventional model. There is a strongly voiced expectation that the program at Smith needs to look '*right*,' seem '*normal*,' be '*respectable*,' and appear '*credible*' to the wider, academic engineering community in order to achieve its counter-conventional aspirations. While ABET accreditation reinforced traditional expectations and criteria of normalcy, it offered in exchange material certification and an opportunity to press the alternative agenda. Less concrete and yet as powerful, local institutional features of a single-sex liberal arts college also worked to limit implementation of a more conventional, thus respectable and credible, engineering program. It appears to be very difficult to escape the need to bow to key stakeholders in the process of curriculum and program design, to resist the long history of organizational social control that has marked all modern professional education, including engineering. Thus, like many experimental research subjects, the faculty in the experimental engineering program provided much of what the audience expected.

Although the pressures toward conformity with the '*benchmarks*' of '*credible*' engineering were enormous at Smith, the more immediate context of Smith's liberal arts tradition may yet open a crevice for innovation and change in ways not wholly anticipated.[30] Further, the impact of the context of Smith's liberal arts culture on engineering students' interpretation of their professional role and responsibility in society remains an equally important and unanswered question, though one we plan to pursue in other aspects of this research project.

### *Inventing the innovative engineer at Olin College*

#### *Normativity, organizational goals, and mission*

The trustees of the Olin Foundation allocated resources to create a brand-new school of engineering, including funds for a 2-year period (2000–2002) to design the curriculum, organize activities of student life, and put all administrative systems into place before admitting students.[31] In 2002, Olin admitted its first class of high-quality students.[32] Like Smith, Olin is a residential, undergraduate college. In contrast to Smith, however, Olin focuses exclusively on the engineering sciences with a mission to explore, test, and implement 'innovative engineering curricula' and to educate 'entrepreneurial' engineers who appreciate and understand the challenges of 'innovation and continuous improvement.'[33] Olin builds from the ground up – new land in Needham, Massachusetts, and new faculty recruited to work on the design of a new engineering curriculum – as close to an organizational *tabula rasa* as one might observe in higher education degree-granting programs.

Olin describes its new engineer as an entrepreneur, a sophisticated reader of the social landscape whose communicative and interpersonal skills are harnessed through engineering design to forge new technologies and new organizations. Olin's commitment to gender equity is not quite as front and center as Smith's, although the admission policy is designed to ensure gender balance in each entering class; out of a founding faculty of approximately 35 professors and administrators, there are 12 women.

Olin's mission takes its inspiration from Leonardo da Vinci to educate the 'Renaissance Engineer.' The faculty member who suggested the metaphor describes how one of her colleagues always raised the point: '*What Olin Does That Others Don't*,' which was quickly shortened to WODTOD. She describes herself scribbling and coming up with the idea that '*What Olin Does That Others Don't*' is to produce the renaissance engineer, the professional who is '*scientifically astute, entrepreneurial, and artistic*.' Through extensive discussion among the faculty, administrators and a small cohort of students admitted prior to the school's founding for just this planning purpose, the renaissance engineer evolved into the organizing framework for the Olin curriculum, or what came to be called the Olin triangle. The emphasis on scientifically astute evolved into the concept of a person with '*superb engineering knowledge*,' someone who was steeped in the '*fundamentals*,' who '*grasps science*.'

[30] This paper reports data collected in 2003–2004. Future research will need to track the future paths of innovation at Smith.
[31] Kearns et al., "Designing from a Blank Slate," 2005, p. 99.
[32] A focus on recruiting highly qualified students is by no means a new phenomenon in engineering education, particularly as education turned toward a firm scientific orientation in the post-World War II period (Seely, "The other Re-engineering of Engineering Education," 1999).
[33] Kearns et al., "Designing from a Blank Slate," 2005, pp. 98–99.



These claims and phrases were repeated throughout the interviews. Debate around what '*entrepreneurial*' meant came down to the idea that one can '*articulate*' and '*activate*' a '*dream*.' Janet, who is formally trained in music and electrical engineering, described how she '*loved*' this idea of entrepreneurial because it reminded her of how composers describe the process of writing musical compositions. Finally, the artistic: '***engineering can be very artistic … and again a broad definition of art, artistry; it's a feeling of creating***,' she noted. The ideal of a Renaissance Engineer seems to be taking hold in the Olin culture. Faculty, whether part of the original planning or not, described Olin's special pedagogy as a commitment to scientific rigor and engineering design that is leavened by learning how to make things happen with artistry and creativity.

#### *Capacities, means to achieve goals*

To transform engineering education, to instantiate its mission to join engineering to entrepreneurship, the design and organization of the college mimics what it wants to produce: continual change, flexibility, and responsiveness. The mission of Olin is achieved through a shared pedagogy that emphasizes '*do then learn*' in contrast to the conventional curriculum that attempts to instill basic skills (in math and physics) and then use them in engineering problems. Very self-consciously, Olin faculty begin by inverting the common paradigm and with this innovation seek to achieve their larger mission. One faculty member describes how the Olin emphasis differs from traditional engineering education:

> *Like I said before, the do, rather than just–you know, [learn then do] is what makes Olin different. Engineering students have typically sat in classrooms and been lectured to, and they work every third problem in the back of the book for homework, and then for the next class, they do it again. So the contrast [at Olin] is being thrown into solving something, doing something and having to draw on whatever resources are needed to do the solution. And we typically do that, the first time that we offer it in the class that I'm teaching now, a business simulation–well, the comments one of the girls made–or women made, I should say–was that "this is the most do then learn" that she'd ever done in anything, because she didn't have any idea what she was doing, so it all had to be thrown into the pool, and then have life preservers continuously. … And quite frankly, these students are so good they [can] do that.*

Through this model of hands-on, project-oriented, collaborative education, Olin hopes to produce a new generation of leaders who have learned to harmonize engineering with entrepreneurship in team-based settings. Indeed, teams dominate much of the emergent culture at Olin: faculty teaches foundational courses in teams; students are required to work in teams on design projects; and many extracurricular activities revolve around teams as well. Olin also made the decision to do away with departments; rather, faculty are organized as an interdisciplinary community of the whole. With this model that puts interdisciplinarity and teams at the center, Olin seeks to ensure that innovation and continuous improvement are a fundamental part of its educational mission. If the Renaissance Engineer who does and learns simultaneously is Olin's first cultural icon, this open structure of full participatory governance with 360-degree continual evaluation is its second cultural icon. While some faculty expressed reservations about whether the absence of departments is practical, all concurred that the decision complements their mission to educate the renaissance engineer.

Additionally, a commitment was made to incorporate design into every nook and cranny of the curriculum. Thus, Olin's culture is marked by a faculty, undivided by discipline that takes design as seriously as science and engineering. Lest one feel that these ideas have been around in engineering for some time, a faculty member notes that '*Leonardo took a lot of inventions and made them better*!' In other words, Olin may not attract notice because its anchoring commitments are in fact new, but rather because they are made better in execution.

Faculty describe a culture that encourages experimentation in one's teaching, from co-teaching an interdisciplinary course to incorporating a design element into each and every phase of a course to writing across the curriculum. As one professor notes,

> *I mean, I could teach pretty much anything I want. But I wouldn't, just because I value the opinions of my peers and my mentors here. And so, I would never do something that I thought was totally weird, or not applicable to the title or the idea of the course.*

*Constraints*

Although beginning with a blank slate and a strong commitment to invert the conventional sequence of '*learn then do*' to '*do then learn*,' faculty nonetheless express evidence of more general professional constraints. For example, some faculty members describe the inescapable and difficult trade-offs in curricular design between offering students depth in a few areas or breadth of the field. Or with regard to particular courses, as in the quote above, the professor acknowledged the ways in which professionalism places a boundary on innovation by not wanting to do anything '*totally weird*' or that was not approved by his colleagues' valued opinions. Of course, a shared notion of professionalism – what is appropriate – is, by definition, a strategy of social control. The Olin faculty articulates a recognition of these tensions, especially between the desire to be innovative and inventive on the one hand and external and professional expectations on the other. This tension is also centrally expressed in talk about interdisciplinarity. Although this is a faculty that decided not to organize itself through traditional departments, which are conventional administrative units of scholarly disciplines, their training and sensibilities were deeply marked by disciplinary identities and knowledge. Thus, the faculty repeatedly sought to traverse and loosen boundaries that were not administratively present at Olin.

Curricular design is also constrained by professional conceptions of scientific rigor. A close reading of our interviews at Olin, and Smith for that matter, demonstrates that the faculty do not foresee cutting back on basic science or engineering fundamentals to make way for design, invention, artistry, and entrepreneurship. Rather, it is assumed that design, invention, and artistry will be added to the traditional basics of the engineering curriculum. Because math and science are the communicative resources of engineering, despite the fundamental innovation of sequence ('*do then learn*' instead of '*learn then do*'), the cumulative content of the curriculum will always assume a core of math and physics.[34] Moreover, like Smith, as a start-up organization, Olin recognizes that it must be

[34]Reynolds, "The Engineer in 20th Century America," 1991.



taken seriously by key stakeholders, including the broader educational community and industry. The dominant ethos of engineering professionalism captured in its commitment to engineering science acts, then, as a brake on invention and innovation – even on a campus that enjoys a reflexive faculty, abundant resources, and a carefully selected student body. An instrumental, practical professionalism is also demonstrated in Olin's decisions concerning degrees to be granted and ABET accreditation. Few topics garnered as much debate as the discussions about whether to grant one degree in Engineering Science, or three degrees – Engineering Science, Mechanical Engineering (ME), and Electrical Engineering (EE). Some faculty argued that granting one degree in Engineering Science, where students have the opportunity to incorporate their own course designs in specialized fields, would complement the mission and philosophy of the college. It is hard to square a commitment to educate a renaissance engineer with a decision to educate a specialized engineer with a degree in ME or EE. The decision was made, however, to go with the three-degree framework. Though many recognized the philosophical justification for the one degree, practical considerations prevailed. When industry seeks engineers with specialized competence in ME or EE, there is an expectation that this will be denoted on the diploma; if a student had developed a homegrown specialization in ME or EE through a degree in Engineering Science, there is a good chance that many industry recruiters would simply pass over the prospective hire, even if he or she is an Olin graduate. As one faculty member put it:

> *I mean, it's not an easy battle to win [to have a general engineering degree; and] it's not only in academia. But [for] so many in industry, it's like, "We want an electrical engineer, we want a mechanical engineer" ... And I know it's even a problem for biomedical engineers; if you're a bioengineer–if you have a degree in bioengineering, and you're looking for a job at GE's Medical Imaging Department, they [will say] "Well, we want a Double-E, we don't want a Bio-E. We don't know what you do; we don't care about all this other bio stuff. Just get me the Double-E, an electrical engineer." ... But, hopefully by producing really good students who have a solid grounding in a whole bunch of different things [even with a specialized major], we can help take a bit of the stigma of "just engineering" away, at least for our students.*

As this comment suggests, the expectations of the job market trumped Olin's internal philosophical commitment to interdisciplinarity among faculty as they designed the degree programs.

Other consequences may follow. Although the degree in Engineering Science captures the philosophy of Olin, there is a concern that this will be misinterpreted by the broader engineering community because many programs that offer only a general degree cannot secure accreditation, or, as it was explained, a general engineering degree is for '*those who cannot cut the mustard to secure accreditation*.' With Olin's decision to offer both a general and specialized degrees, there is the concern that a mixed message is being sent to students about the goals of the institution:

> *In the sense that we try to support interdisciplinary work, we try to support a lot of self-directed student-[learning]; [but, what we may now be doing is to say], "There's the two real degrees and then there's the fake-O degree" [an American colloquialism that suggests not a real degree].*

It is, then, not just the presence of the three degrees that is problematic, but also that the broader, cultural discourse on the hierarchy of degrees permeates Olin's milieu. Another faculty member pointed out that the three degrees will also have consequences for decisions about faculty hires and, specifically, the need to provide adequate coverage to the degree programs, particularly ME and EE. The emphasis on meeting teaching demands for ME and EE accredited degrees may create higher opportunity costs for hiring faculty who do not fulfill the specific curricular needs of these degrees. One faculty member described the consequences this way:

> *the whole issue of [degrees] ... means we end up hiring a whole bunch of Mech-Es and EEs to offer this program that's going to be approved by ABET; [this] ... is ultimately going to change the shape of the college, right? Because we're hiring these people in lieu of lots of other people that we could be hiring.*

The shadow cast by the decision to secure ABET accreditation was broad and significant. While ABET accreditation is, as one faculty member put it, the '*gorilla*' in the middle of the room, there is a consensus at Olin, just as there was at Smith, that it is essential for the '*credibility*' and '*legitimacy*' of the institution and its graduates. As he explains,

> *Accreditation's been sort of like the gorilla in [the closet]. Accreditation doesn't happen until after we graduate the first class. It took me awhile to understand that. You don't just get accredited on the basis of what you're doing; you literally have to graduate your first class. And so we've had a variety of pre-accreditation reviews, where those people–or at least, those organizations that are responsible for the accreditation–have come in and done kind of practice accreditations with us, so we've spent a lot of time and energy making sure that all the "i's are dotted and all the t's are crossed." I mean, it should be a slam-dunk. Because we recognize that for a place like Olin, it could be extremely.... embarrassing, if it turns out we're not accredited first time through the gate.[35] If we're Princeton, then who cares?*

The ambivalence around the whole accreditation process and the constraints it poses closely echo those of the Smith faculty. There the analogy was to CalTech, but the underlying message is the same: ABET accreditation definitely hampers the potential for creativity in engineering, but the price of not securing accreditation is simply too high to forego.

The administration began with the premise that ABET accreditation was necessary. Indeed, from some faculty members' perspectives, the administration was unduly concerned about accreditation and that had consequences for innovation and change in pedagogy and curriculum from the very beginning. As one faculty member put it,

> *I think [the] administration at Olin has different priorities [and], it's interesting, accreditation is a big one. I think there's a tremendous concern–I'd almost say a fear–regarding the accreditation process. [There is] the concern that we get accredited; the fear that we may not. And so I think that is causing the administration at Olin to take a very conservative stance about some aspects of curricular development. There are cases where, we're basically saying, "What's the most conservative, negative position, that ABET or NEASC–the two big accreditation agencies–what's the worst position that they might take at Olin?. Have we [prepared] our curriculum to answer the most negative challenges? What's the most mean-spirited, pessimistic person who could come here to accredit us, and what would they try and poke holes in, how can we be bullet-proof right to that?" And I think that's a very unpleasant way to go about this, as a way of handling curriculum. .... So there are aspects of, where, something really innovative comes up, and the faculty seem excited about something we might do, and then it gets watered down at some point due to some potential concern.*

[35]Olin was visited by ABET team in October of 2006 and received its full accreditation in August of 2007.



For most of the faculty, however, ABET accreditation is viewed as somewhat of a necessary evil:

> *It sucks to have to play the ABET game, but it would suck for our students if we didn't, because they need that seal of approval, just to get recognition [in the job market]. And, you know, [ABET is everywhere; for example,] everything you apply for, grants and–everything I apply for, there's always that line that says "two or four-year accredited institution." It's in the boilerplate. No one even thinks [about] what it means.*

Yet other faculty are even more comfortable with ABET, suggesting that the new, post-2004 criteria provide more latitude for developing the kind of curriculum that suits Olin's mission. As one faculty member noted,

> *ABET revised their criteria to be a little less restrictive, as far as, 'you must have exactly this class and exactly that class;' [now,] it's more like, 'we teach these competencies, that's what we're addressing in classes now.' So, I could design the course that I wanted to; I could make it very hands-on, bring in very sophisticated lab project that the students work on that I can't imagine trying any other place.*

Echoing our findings from interviews with Smith faculty, constraints on innovation emerge from faculty's own professional commitments, their tacit assumptions about what constitute foundational technical expertise in engineering, and from the accreditation process itself. Unlike Smith, however, which offers one degree in Engineering Science, Olin, as a consequence of its closer identity with industry, compromised philosophical principles to respond to the practical demands of employers who want specialized degrees with recognized names. How the generalist degree in Engineering Science fares at Olin, even though it is closer to the mission and goals of the institution than the specialist degrees, remains an open question. As these findings suggest, while Olin built from the ground up, it draws from materials with a strong, traditional imprint.

### *Time/Space*

Just as Olin erected its campus on fresh ground and its mission as well as means to accomplish its new goals, it also had to invent the tempo and timing of the Olin education. The core courses, referred to as 'foundations,' are taught by a team of faculty in an inter- or non-disciplinary fashion where math and physics are learned in the process of solving basic engineering problems. These foundation courses include a design component. There is a required design project each year. Like the Smith students, during years three and four, Olin students specialize in an area of engineering expertise (e.g., electrical and mechanical, various concentrations in bioengineering, computers, materials, and systems) and, as one faculty said '*realize their goals*' through a capstone project in the fourth year. However, unlike Smith, Olin's curriculum also includes an emphasis on comprehensive testing, or what Olin faculty call '*gates*,' where students are required to complete end-of-year, week-long assessments that include written and oral exams as well as team exercises.[36]

[36]Kearns et al., "Designing from a Blank Slate," 2005.

This temporal structure, along with the non-departmental faculty organization, is a distinctive, innovative mark of the Olin education.

The curriculum is confined within the traditional semester, academic year, and four-year degree calendars. Olin also heeds to some fairly conventional and familiar academic values, most notably a commitment to faculty engagement with scholarship and research. Olin faculty, like their counterparts at Smith, describe endless time and energy devoted to thinking through effective, innovative, and creative teaching styles. As many faculty noted in our interviews, they found themselves caught between time consuming demands to develop new practices and procedures that would denote the Olin stamp while, at the same time, trying to fit in the typical activities of conventional academic careers. Managing an innovative engineering education along with a conventional academic career produced its own professional dilemmas.

As participants in a start-up, faculty were involved in inventing much of what has come to demarcate the Olin experience. Commenting on curriculum development, one faculty member noted that there were no 'textbooks' that had to be followed:

> *So, I could design the course that I wanted to; I could make it very hands-on, bring in very sophisticated lab project that the students work on that I can't imagine trying any other place .... Designing four different courses in the four years we've had students here, so that's exciting. It kept me busy, but it's exciting.*

'*Busy*' and '*exciting*' capture as well other faculty comments on curriculum development. Whether from the standpoint of each faculty member's efforts to develop the new innovative courses or their collective efforts to design an innovative and comprehensive curriculum, faculty found themselves faced with the reality that there are only so many hours in a day and, hence, more realistic solutions needed to be fashioned.

Comments of Olin faculty about how they find a '*balance*' between teaching, service, and research do not sound different from their counterparts at Smith, if not at most universities. Just as many faculty might note that they work 80-hour weeks, so this Olin professor explains her search for a balance between teaching, research, and service:

> *it's a really difficult–it's really hard to balance [teaching, service, and research]. It's so easy to get sucked into [curriculum development and other stuff]; my first year here I did basically no research. All I did was get my funding and footing and do stuff for the college.*

Explaining that this semester has been better because she was able to get some research done, she explains that she was

> *basically working 80-hour weeks because I had a bunch of research things I had to get accomplished; in addition ... [I was] writing grants; [and, I was] not shirking my teaching and service responsibilities ...*

Having come from another institution, this professor notes that all of this grant writing and research was the same at her previous institution and everywhere else; however, the service commitment at Olin is higher

> *And of course the stressful thing is that obviously, at any other institution, our service responsibilities would not be anywhere near as high. I mean, there would be either, research first, then you do teaching, then you do service. And here, they're actually about equally balanced. And it's a struggle then to find the time to do the research.*



Although, no doubt the service component was especially taxing in the early years of the school, certainly the ambition to innovate will always be constrained by finite time. The broader implication is that, despite heavy time commitments for inventing and planning, conventional expectations were nonetheless reintroduced. Olin faculty are expected to balance their time around teaching, research and service, the conventional triad for faculty evaluation but without tenure. Faculty are evaluated every five years for contract renewal. Although not a tenure review, the process looks very similar to a tenure evaluation including creation of a dossier, obtaining letters from internal and external evaluators, and performing internal and external reviews. The decision of whether to renew or promote a faculty member is based largely on the traditional triad with emphasis on '*intellectual vitality*.' In some faculty's experience, however, that criteria of intellectual vitality have become more and more about traditional research than had originally been anticipated.

In sum, the findings from these faculty interviews at Olin suggest that ABET, even in its looser, more qualitative, post-2004 version sets parameters on just how far Olin, like Smith, will go in turning engineering pedagogy on its head. At each stage of planning and development, ABET cast a shadow over discussion that brought decisions from the realm of the innovative into the familiar. That said, this is precisely what ABET, an agent of organizational social control, is supposed to do. Yet the constraints implicit in ABET criteria operate in conjunction with others. As we have seen, the faculty's well-cultivated commitment to professionalism also puts brakes on going too far over the line by way of innovative curriculum. Finally, not all of the Olin faculty are ready to throw out the engineering science baby with the fresh bathwater: there are many who feel at home with a positivist, ahistorical, and empirical engineering science; their goal is not so much to do engineering science differently but rather to do it right. This is what attracted them to joining the faculty at Olin. While Olin enjoys an organizational *tabula rasa*, the findings from these interviews demonstrate the ways in which the organizational field of accreditation, professionalism, and higher education affect that slate. To be sure, Olin will enjoy a distinct cultural marker in the landscape of engineering education; one might speculate, for example, that they will give energy and vitality to a better way to teach design. But it will still have the look, feel, and familiarity of engineering pedagogy and its debates.

## Discussion: accreditation and the power of an instrumental logic

Although our findings show that the organizational constraints and opportunities at Smith and Olin are different, both projects unfold within a shared cultural and institutional framework. Whereas Smith enjoys both the opportunities and limitations of a liberal arts tradition, Olin enjoys the opportunity and constraints of a start-up organization. Both schools are located squarely within the broader culture of engineering professionalism that secures the license to practice through institutional accreditation. While the accrediting agencies have succumbed to pressures to allow for more individualistic or idiosyncratic expressions of engineering education,[37] accreditation as a process cannot escape its inherent boundary framing activity: accreditation determines how far one can go and still be legitimately within the engineering community. The process invites, even if it does not demand, the faculty to represent the curriculum as a set of mechanisms – specifiable procedures – for producing measurably competent professionals. As such, accreditation is a critical part of the boundary-work sustaining professional authority,[38] enacting the responsibility, legitimacy and credibility of self-regulation that lies at the heart of professional authority and autonomy. Whether in its old, bean-counting or its new mission-driven guise, accreditation (re)produces a narrow, instrumental educational program.

Despite the pressures posed by accreditation to conform to an instrumental logic and the steps taken at the respective sites toward that end, the faculty at Smith and Olin began their projects with a profound critique of traditional engineering education. Guided by their respective critiques, faculty at each site took specific steps to overcome the narrowness of an instrumental, professionalized engineering education. As our findings show, the faculty at Smith recognized and built from – indeed celebrated – the ways in which the liberal arts culture at Smith might challenge the core principles of engineering itself. The faculty at Olin took seriously their metaphor of a 'renaissance engineer' and elevated design – tinkering, hands-on, and 'dirty' work – to a centerpiece of all aspects of engineering curriculum. The liberal arts culture of Smith and the 'renaissance culture' at Olin may present crevices for more fundamental reform.

In the case of Smith, the liberal arts culture builds from a very different set of assumptions about the goal of a college education. The historic status of the liberal arts derives from the self-conscious insistence that a liberal education cultivates in students a taste for and ability to tackle difficult, often indeterminate moral and ethical dilemmas.[39] The liberally educated student develops a critical orientation by locating knowledge claims in multiple frameworks, competes among lineages and traditions of inquiry, contemplates alternative points of view and ways of making knowledge, engages in focused inquiry about what constitutes truth and knowledge, recognizes differentials of power and position, reads extensively and writes well, and develops that mental agility and adaptability that helps one confront and embrace the ambiguous, the mysterious, and the non-rational. How the clash of cultures between the liberal arts and engineering at Smith will play out remains an open question, but it is nonetheless a clash that is ripe with possibilities for creativity, serendipity, and unpredictability.

In the case of Olin, the centrality of design and hands on work is a nineteenth century image of engineering in twenty-first century guise. The findings from our interviews suggest that the Olin faculty want to have it both ways, to prepare students who are steeped with the scientific rigor and engineering logic required by traditional programs while, at the same time, transforming the enterprise through the hands-on, dirty, messy design of 'real world' projects. They point out that da Vinci did not always invent the 'new'; rather, he did what everyone else was doing brilliantly. If Olin does it 'better,' the constant clash between scientific/engineering technique and hands-on design may create an environment ripe with creative, serendipitous and unpredictable pedagogical moments.

[37]Downey and Lucena, "Knowledge and Professional Identity in Engineering," 2004.
[38]Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science," 1983.
[39]Strauss, *Liberalism*, 1968.



Both Smith and Olin, then, develop programs that are familiar given the institutional logic of engineering education. Yet both present crevices for unintended consequences of learning how to navigate uncertainty, serendipity, and judgment. Whether Smith and Olin students develop a professional identity through these crevices that is distinct from their peers at more traditional engineering programs remains an empirical question that we explore in subsequent phases of our larger project.

Questions about the Olin and Smith experiments in engineering education remain. How will students construct an engineering identity at these sites? At Smith, as students traverse the course requirements of Latin Honors, junior year abroad, and other opportunities of a liberal arts community, how do they come to understand what it means to be an engineer? At Olin, as students constantly immerse themselves in the thorny challenge of hands-on design, how do they come to understand what it means to be an engineer? Do these emphases at Smith and Olin, albeit different, nonetheless create opportunities for students to cultivate an understanding of their professional calling in a way that is distinct and different from their peers?

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