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Introducing Engineering as a Socio-technical Process

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Introducing Engineering as a Socio-technical Process

Abstract

This paper describes efforts to introduce engineering as an inherently socio-technical process to engineering and other students at Lafayette College. Our efforts comprise an attempt to present engineering as a component of the liberal arts in two ways: one, that it shares creative, innovative, and cultural elements with other liberal arts disciplines and, two, that it is a mode of inquiry and building understanding of the world. Our approach follows from the view that while engineering as a practice is widely understood to include skills in calculation, design, technical dexterity, communication, imagination, values, and social relations, introductory coursework often focuses on engineering in isolation from the larger socio-technical context that holds those skills together.

A focus for these efforts is the piloting of a course introducing first-year students to engineering as a socio-technical mode of engagement. The new course, taught within the structure of a required "Introduction to Engineering" framework, develops a socio-technical concept of technology as a system and engineering as a multi-faceted (not strictly technical) activity. This follows from innovations in engineering pedagogy from decades of STS scholarship, and from the emerging field of engineering studies scholarship. This paper discusses the unique features of this effort at a small liberal arts college, and concludes that the pilot implementation was successful in achieving the desired outcomes. Further, while the authors leveraged institutional advantages, the methods and content should be transferable to other types of institutions.

Introduction

In our experience, engineering is often viewed as a discipline for people who "don't want to read or write much." This has been particularly true of a sub-set of undergraduate students who see engineering as a career path in which they can leverage their aptitude for math and science into a stable, well-paying career. In this worldview, engineers are technical experts who are recipients of problem definitions and apply scientific and mathematical principles to solve the problems in a technically elegant and efficient manner. This caricature of the engineer as an applied scientist/mathematician working outside of society is outdated.

Over the last several decades engineering leaders have emphasized the role of the engineer in society through documents such as the National Academy of Engineering's *Engineer of 2020*[1], the American Society of Civil Engineers' *Body of Knowledge*[2], and ABET's *Engineering Change* report on the effects of the EC2000 accreditation criteria[3]. Further, increasing concerns about sustainability, as evidenced by these documents as well as recent changes to engineering codes of ethics, require engineers to understand themselves and their work as existing within the social, environmental, and economic context of the present and the future.

However, as we hear these calls for broader thinking and expanding the non-technical aspects of engineering education, engineering continues to advance as a technical discipline, simultaneously leading many to believe that undergraduates should learn more technical content. To make matters worse, higher education institutions face pressures (and requirements, in the case of many state universities) to reduce the number of credit-hours required to obtain a degree in engineering.

The engineering programs at Lafayette College are addressing these challenges largely through integration of these broader issues (e.g. societal context and communication) throughout the curriculum, beginning with the required Introduction to Engineering course taken by most prospective engineering majors during their first semester on campus. This paper presents a case study in introducing engineering as a socio-technical process in the first semester. We first provide the broader institutional context in which this effort exists; this is followed by a more rigorous discussion of the theoretical and methodological underpinnings of viewing and teaching engineering—and technology—as a socio-technical system. The next sections explain the model for the Introduction to Engineering course, detail the structure of the pilot course, and assess its effectiveness. We conclude with observations about the directions of this effort at Lafayette College and key insights that may be transferrable to other institutions.

Institutional Context

Lafayette College is one of a limited number of small colleges that offer degrees in liberal arts and engineering disciplines. Further, it is one of the few institutions in the U.S. to offer an interdisciplinary Bachelor of Arts in Engineering in addition to ABET-accredited disciplinary engineering degrees.[a] In the liberal arts and sciences, students can choose from 47 majors housed in 17 departments and 10 interdisciplinary programs.[b]

In 2011, the faculty concluded a major revision of the college's common course of study (CCS) that, among other changes, requires all students on campus to meet all CCS requirements.[c] One change to the CCS that may have little practical effect but is a major change symbolically is the ability of students in the liberal arts and sciences to count engineering courses as part of their CCS requirements. That is, under the old CCS, a student who was not an engineering major who took an engineering course had to count it as an unrestricted elective; under the current CCS, such a course would count toward a distribution requirement. This change is one step toward better integrating engineering and the liberal arts on campus. Most would agree that while engineering majors benefit enormously by taking classes from the strong liberal arts and science programs on campus, few liberal arts and science majors interact with engineering students or faculty in an engineering classroom.

At approximately the same time as the CCS revision, the four B.S.-awarding engineering departments also revised their curricula to 1) reduce the total number of courses required for graduation from 38 to 36 and 2) decrease the number of required science, math, and engineering courses to increase student flexibility within the curricula. Both of these initiatives took place in the context of increasing interest among faculty members and students in interdisciplinary

[a] Lafayette College awards ABET-accredited Bachelor of Science degrees in Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, and Mechanical Engineering, each housed in its own department, as well as a Bachelor of Arts in Engineering degree, which is housed in the Engineering Studies Program. Students may also pursue a formal dual-degree program in which students earn both one of the ABET-accredited B.S. degrees and a Bachelor of Arts in International Studies.
[b] An additional 13 interdisciplinary minors, beyond those associated with a major, also are available.
[c] Prior to the change, engineering majors completed a modified version of the CCS.

problems and recognition of the permeability of traditional disciplinary boundaries. All four engineering departments at our institution offer a large number of laboratory-style courses in which students gain hands-on problem solving and design experience; retaining this focus was a priority.

As mentioned above, the Engineering Studies program administers the Bachelor of Arts in Engineering degree. The faculty of Lafayette College established the degree in 1970 with the goal of producing graduates who could bridge the gap between engineering and the liberal arts. The mission of the program is:

> *To provide a rigorous liberal arts curriculum built on an engineering foundation that prepares graduates to effectively address society's increasingly complex challenges. Graduates gain expertise in examining the place of engineering and technology in society, with interdisciplinary skills to lead public technology debates around issues related to policy, management, economics, and the environment.*

Given the nature of the Engineering Studies program, it is not surprising that program faculty are deeply interested and involved in efforts to bridge the gap between the liberal arts and engineering not just for program majors but more broadly for all students. In the case of engineering majors, we believe that students would benefit from being asked to make more explicit connections between their liberal arts coursework and their engineering coursework. In the case of liberal arts majors, we believe students would benefit from a basic understanding of the engineering design process, increased awareness of the role of technology in society, and a greater comfort level with technological discourse.

The Case for Teaching Engineering as a Socio-technical System

The introduction to engineering at Lafayette College is thus framed by local characteristics, while following from and speaking to broader curricular debates in the field of engineering education. By virtue of its size, administrative structure, and curricular flexibility, Lafayette also has a record of espousing interdisciplinary activity and cross-campus collaboration. While it would be over-stating it to suggest that interdisciplinarity and liberal arts education are synonymous, course design at our institution is often structured to allow for interdisciplinary pedagogy by leveraging the ideals of the liberal arts for cross-fertilization and wider extra-disciplinary debate. Looking just to the three engineering-based authors of this paper, for example, Rossmann co-teaches a course with an art professor and offers another in American Studies; Cohen teaches courses cross-listed in environmental studies and engineering while offering a course in the history department; and Sanford Bernhardt works on multi-disciplinary grant-funded research with professors in economics and computer science.

This culture of disciplinary interaction is also common to the engineering student experience. The means by which students in the engineering program develop their own identity as engineering majors is crafted through their course selection across the sciences, social sciences, humanities, and engineering; through daily interaction in those courses and as part of the general campus community (curricular or otherwise) where interdisciplinary interaction is *de rigueur*; and by virtue of the interdisciplinary content of some engineering coursework, especially for majors in the Engineering Studies program. It is within that traffic of disciplinary interaction that "ES 101: The Introduction to Engineering" sits.

Engineering as a liberal art

A motivating factor in the course design has been the view that engineering itself is one of the creative, liberal arts. Like practitioners of literature, theater, and the visual arts, engineers are fundamentally involved in the act of creating new things, addressing persistent problems with new solutions, and crafting innovative visions and novel approaches while fashioning the infrastructure of our world. To be sure, the engineering milieu demands training in areas that differ from a traditional liberal arts curriculum, most obviously through more specified attention to technical, quantitative and material knowledge. Yet the core notion that engineering is a creative art remains. That notion offers a range of possibilities for envisioning the engineer as learning in a world common to artists, writers, scientists, and other inventors.

One such possibility is the chance to understand the technologies engineers design, like artwork, not just as things people make and have, but as activities people perform, ideas people hold, and social visions people put into material form. Key to introducing students to this image of engineering are the concepts of technology as a socio-technical system and engineers as socio-technical analysts. Both concepts are intended to bolster and elevate the identity and social standing of the engineer. Both carry a dynamic element as well.

Technologies as socio-technical systems, for instance, depend on the continuing production and reproduction of the system. Engineers, consumers, community members, and other affected users constantly create and re-create the meanings, forms, and substance of technologies in ways that are irreducibly both social (a term we use for ease of reference here to stand in for 'non-technical') and technical. As the sociologist Steve Matthewman has written, technologies are objects, activities, and knowledge all bound up together[4]. Or, as Jurgen Habermas put it some time ago, technologies are congealed natural knowledge[5]. Importantly, once in that congealed material form, they do not lose their intellectual, social character. Casting engineers as socio-technical analysts allows for this dynamism to remain central to the engineers' identity—the engineer works to design systems of social and technical features in an on-going reconstruction of the world. It also provides a basis from which to explore the socio-technical process of design work, as we do in the introductory course.

Technology and engineering as socio-technical systems

In keeping with this observation about the dynamism of technologies, we use the term socio-technical systems to refer to technologies in our Introduction to Engineering. This comes from recognizing that successful engineering design and technological development involves awareness of and design within social, political, economic, and cultural contexts that supersede individual engineers and strictly technical metrics. Understanding technologies as socio-technical systems also provides a rhetorical advantage in the classroom. It helps avoid the perception of a binary division between technology and society, a division that could further the impression that technologies sit on one side of the table and society on the other. We argue instead that a constitutive part of the identity of engineering activity (technology design) is both technical and non-technical (taken to refer to the social, economic, political, ethical, etc.) from the start. From that view, engineering students in the course have the opportunity to develop an identity that is likewise mutually constituted by attention to technical and non-technical factors. We position this socio-technical concept at the core of the coursework as a way to help students understand technology design as including social metrics (like empathy, values, preferences, even resistance) and technical measurements (such as efficiency, productivity, operational success).

The view of technologies as socio-technical systems stands in distinction to a common public understanding of technologies as disembodied machines. For example, twenty-first century views expressed in the public sphere often equate "technology" with "computers" in the way that earlier public views equated technology with machines, tools and industry[6]. It remains common not just in the mainstream media but in the views of undergraduates that technologies are machines, objects, or things. As Erik Schatzberg[7] and David Nye[6] have shown, this popular modern conception of technology is but a century or so old, tracking along with the modern era of industrial production. What most people have considered technology over the past century had been understood as craftwork and mechanical arts in the centuries before that. This is not a mere semantic point. Craftwork and arts were processes, ways of doing things, and activities. They were dynamic and labor-based, rather than static and product-oriented. The evolution of public views during the twentieth century tended to treat technologies instead as isolated and asocial things. Such a view allows for and propagates the perception that technology and society are distinct categories: the former material and technical, the latter human and value-laden. If engineers are defined as those responsible for the design and production of technologies, the view of technologies-as-asocial-things also fosters the image of engineers as working outside of society.

Research in the latter decades of the twentieth century opened up new views of technology that make such a static and a-human concept of technology untenable. This work has often been grounded in historical and anthropological research and often produced by scholars of Science and Technology Studies (STS). It has revealed the complex and multi-dimensional identity of technologies by drawing from empirical research into the public character and history of technologies. We find much of this research manifested in schools of thought like actor-network theory (ANT), the social construction of technology (SCOT) and the social shaping of technology (SST) [8, 9, 10, 11, 12, 13]. Those schools of thought have their own distinctions and practitioners of each continue to work out the differences between them, but in common they each find and promote an understanding of technology as mutually social and technical.

Because technologies are designed by people, it follows that technologies are not divorced from the realities of human culture and our attendant moral and political concerns. Those non-technical aspects cannot be checked at the design door, as it were, nor held outside of the technologies engineers create. Not only have scholars found this always-political identity of technologies, but further research into the actual operation of technology construction and use shows the value-ladenness of technologies. Rather than disembodied machines, that is, technologies are material manifestations of deeper cultural and political exercises.[d] Examples of this work stretch from the historical contingency of the very idea of technology-as-progress[14], as gendered[15], as tied up in larger political negotiations[10], and as culturally dependent not just

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[d] They may actually be non-material systems too, if one were to consider, for example, software and computing systems that have digitally encoded data as their center, data that cannot be measured, weighed, and manufactured like a machine.

because of individual value commitments but even at the scale of national-cultural values[16]. Perhaps stated differently and more straightforwardly, yes, to engineer is human.

Folding concepts of technology and engineering education reform together

In our work to consider how to embed these concepts into an introductory course, we were struck by the limited (though not absent) engagement between two tracks of research over the past decades. One is the just-summarized work on concepts of technology in STS; the other is research about educating the engineer of the future by engineering educators. There is indeed a long-standing commitment to educational reform by engineering professionals that asks for engineers to understand and gain competency in realms beyond the technical alone. As Bruce Seely describes it in the NAE's *Educating the Engineer of 2020* report, such debates over engineering education reform are as old as formal, codified engineering education itself[17]. This commitment to reform, like modern public views of technology, is also roughly a century old.

Seely summarizes this constant zeal for reform in the United States specifically, from the Mann report of 1918, to the Hammond report of 1940, to the Grinter report of 1956, to widespread curricular and administrative reform in the 1960s and 1970s, to ABET reforms in the 1990s and the NAE's *Engineer of 2020* initiatives of the past decade[17]. Their emphases have understandably differed as the century and its socio-political dynamics shifted. Yet each spate of reform has sought to enlarge the core identity of the engineer from a technician skilled at calculation and fabrication to a professional member of the wider culture. In that goal of professionalism, engineers are public agents whose responsibilities and skills are part of the socio-political dynamics of their communities. All efforts at reform, that is, have asked engineers to understand their identity as including features beyond the technical alone. ABET 2000 criteria provide only the most notable recent case with its inclusion of a series of communications, ethics, and professionalism standards. While those standards may be treated as additional, subsidiary, and extra-engineering criteria, we sought to engage the two tracks of research—concepts of technology and work focused on engineering education reform—and consider how to integrate them in the classroom. In doing so, we not only fit into a pattern of consistent reform, but find ourselves encouraged by a spate of work in just the past few years to develop a more theoretically rigorous account of engineering in society [e.g. 18, 19, 20].

Our goal in envisioning the Introduction to Engineering has thus been to fold together reform efforts in engineering education with research from STS that conceptualizes technologies as socio-technical systems. The course discussed below begins with socio-technical concepts as a way to enhance the range of skills that engineering education is intended to teach and to foster the status of the engineer as a professional with social responsibility and public engagement. It asks for engineers to cultivate their identity as technology designers cognizant of foundational attributes inclusive of technical and non-technical skills.[e]

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[e] The spatial metaphor that helps promote this vision is important as well. Instead of proposing a radial, atomic model, with the core technical attributes in the nucleus and so-called "soft" skills of communication, economic attention, and cultural value awareness surrounding the nucleus, technologies as socio-technical systems suggests a playing field (admittedly, it may be uneven) with all of those attributes as members of a foundation rather than competitors for the core.

A Case Study

Background & Motivation

The conceptual and historical context noted above helped motivate our course re-design. More pragmatically, the immediate pedagogical motivation to re-think our institution's Introduction to Engineering course was tripartite. First, as engineering curricula were streamlined and redesigned, it was desirable for each required course to "pull more weight" by delivering more value to students. Second, we wanted to "set the stage" for what was to come: both to provide foundational technical preparation in CAD, design, and analysis, and to establish student expectations of engineering as a socio-technical enterprise. Third, as capstone and other design projects became increasingly multidisciplinary, we hoped to develop a common foundation in the design process, with students from all engineering majors (and any non-engineering students who choose to enroll in Introduction to Engineering) learning a common, shared language of design.

The redesigned course model for our institution's Introduction to Engineering consists of two seven-week modules taught by faculty from different disciplines, chosen by students from a menu of several alternatives; additional instruction in engineering graphics; and co-curricular activities that introduce students to the different engineering majors offered, creating opportunities for interaction with upper-division students, alumni, and practicing engineers in each field. The discussion that follows is of one seven-week module, focused on engineering design.

Like other Introductions to Engineering [e.g. 21, 22], this course provides a cornerstone design experience, and endeavors to involve first year students in an engineering design environment that emphasizes collaboration, communication, and interdisciplinarity. More uniquely, this Introduction to Engineering module introduces design as a method not simply of problem solving, but of *problem defining:* through the development of empathy with all stakeholders and learning about their (geographical, social, cultural, environmental, etc.) context, students establish a design problem statement [23, 24, 25]. This holistic, user-centered approach is sometimes known as design thinking[26], and establishes engineering design as inherently socio-technical in keeping with the core concept of technologies as socio-technical systems summarized above.

As an engineering course in Lafayette College's liberal arts environment, this Introduction to Engineering must both 1) help students appreciate engineering design as a "way of knowing" or "mode of inquiry," to be integrated with other facets of a prismatic liberal education; and 2) prepare students for professional engineering practice. While these two purposes are often posited to be in conflict, we have found both to be fulfilled effectively by a socio-technical introduction to engineering design.

Design as a "way of thinking" was first explored rigorously by McKim[27]. It is an outlook that has been adopted at Stanford, Dartmouth, and elsewhere[28]. Students may then integrate design into the array of perspectives and methods that comprise a liberal education. The socio-technical design process, taught at our institution using a problem-based learning (PBL) approach, is a method that students can apply in non-engineering contexts, just as they might transfer methods of humanistic inquiry and close reading to texts outside humanities courses.

Design is often identified as an opportunity to develop skills relevant to professional engineering practice. For example, Frank et al. describe a "Design and Practice" sequence as a "cognitive apprenticeship"[29]. In our course, students repeatedly apply the design process to a wide range of situations; this type of problem-based learning (PBL) has been established as an effective pedagogy for developing "expert professional practice"[30]. The design process, like a PBL cycle, is iterative: student teams identify or are presented with a complex, ill-structured problem; students define the problem and identify the skills necessary for its solution; students build their knowledge base both independently and cooperatively, and repeat the cycle until they have arrived at an acceptable solution. In both engineering design and other PBL processes, solutions are non-unique and context-specific. And in both contexts, having students begin with the socio-technical concept of technology helps foster a more durable and culturally astute set of considerations when those students perform the iterative process. We see this as corroborating Dym et al.'s labeling of PBL as the "most-favored" pedagogical model for teaching engineering design, citing its potential for positive impact on retention rates, student satisfaction, diversity, and learning[31].

Course content

Developing the course content involved keeping both aspects of our mission in mind: teaching engineering design as a way of knowing, a broadly relevant method for problem discovery, definition and solution; and also developing students' professional preparation. The vocabulary of design used in the course was drawn from the IDEO/Stanford d.school version of the design process (Figure 1), and from the textbook developed at Harvey Mudd College[32].

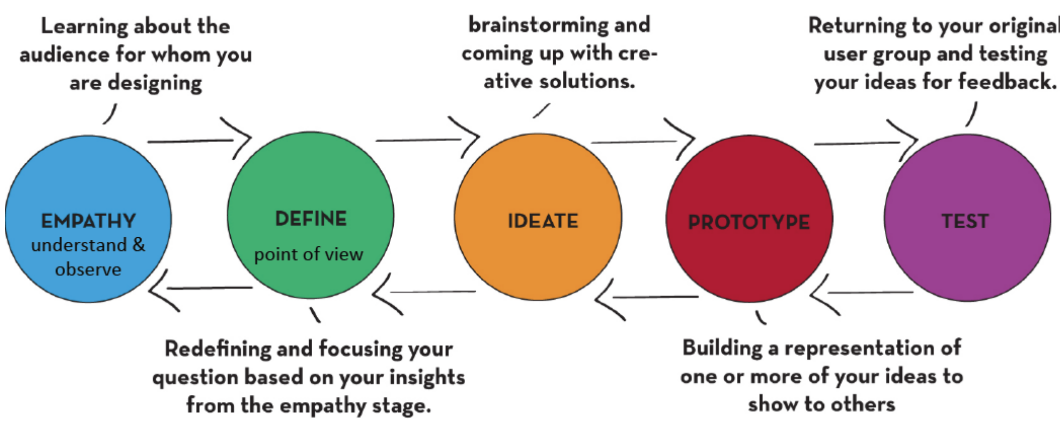

Figure 1. Engineering design process, adapted from Stanford d.school

Course topics included: an introduction to the design process; case studies such as the evolution of bridge design and the way the properties of available engineering materials informs the form and construction of structures, or portable music players and the "Walkman effect" on social interactions; team dynamics and communication skills; methods and uses of prototyping; using CAD to represent designs; and using systems modeling and MATLAB to analyze them. The classroom was also an interactive design studio, in which students actively engaged with the design process, including: performing design thinking exercises to develop devices and processes; identifying relevant stakeholders and appropriate questions for the design of a public park; and reverse engineering a common device.

Through these activities, students developed an appreciation for the need to consider ethical, environmental, and social factors throughout their design process, not as an aside or afterthought. From the initial identification of relevant stakeholders and foundational questions – "who you need to talk with, what you need to ask them, and when you need to interact" – the design process was understood as a socio-technical enterprise. As Pfatteicher notes, "people must take center stage among engineers' concerns," as effective engineering design "requires an engagement with those people one wishes to help, rather than behaving as technological missionaries"[33]. Such engagement requires empathy and socio-technical expertise. Students also practiced the identification of what *other* expertise might be valuable at various stages of the design process, enhancing their appreciation of non-engineering disciplinary expertise. For example: what can psychologists help us understand about working on effective teams? What can social scientists help us understand about developing empathy for our users through interviews and questionnaires? This helped them have a "felt need" [e.g.34] for multidisciplinary design teams.

As an introductory course, this class is well positioned to welcome students into the engineering profession, and to help them understand the professional context in which they will apply the engineering design process. Through lecture, discussion, and reading, students learned that the engineering profession is defined by its social responsibilities and values, and by an authority derived from education and expertise. The historical development of engineering into a profession highlighted the engineer's role in social development and progress; the tradeoffs necessary in engineering decision-making; and the need to anticipate "unintended consequences" and identify stakeholders who may be silent or lack social power.

Student learning outcomes are listed in Table 1.

Student work included several design projects, with documentation in the form of hand and CAD drawings, written descriptions, and oral presentations; design *problem definition* assignments; and writing assignments in which students reflected on their experiences and responded to reading assignments. This work was assessed to evaluate achievement of student learning outcomes, and to guide further refinement of the course.

Assessment

Faculty assessment of student work indicated that they had attained the student learning outcomes for which the course was developed. Reviewing students' writing revealed that they appreciated the need for, and challenges of, establishing empathy in various contexts; and that they had begun to understand the tradeoffs and ethical decision-making processes that would be required of them as engineers. Faculty rubric assessment for six offerings of the course (totaling 140 students) is compared with student survey data in Figure 2.

Table 1. Student learning outcomes

While completing this Introduction to Engineering module, you will:	*Relevant ABET criteria*
• develop an understanding of design as a process	
• have an introductory design experience	3c
• work with engineering graphics software to communicate designs with others	3g, 3k
• work with MATLAB to analyze proposed designs	3k
• hone your ability to work on a design team	3d
• gain experience in visually and orally conveying engineering information	3g
• enhance your engineering intuition and judgment	
• reflect on the importance of ethics and societal considerations in the practice of engineering design	3f

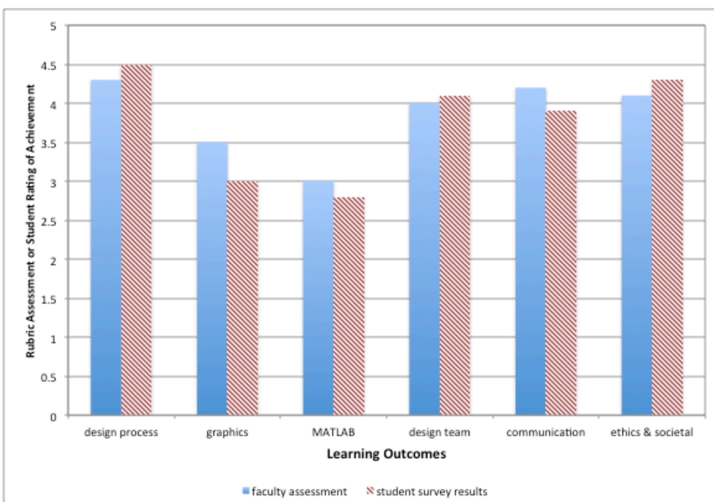

Figure 2. Faculty assessment of student outcomes, and student survey data

Faculty and student assessments are in good agreement. It is interesting that both students and faculty rated the achievement of “technical” outcomes lower than that of other outcomes. This reflects the relative emphasis of the course on these outcomes. Furthermore, anecdotal evidence in concert with the assessment results suggest that it may also be because an introduction to subjects such as engineering graphics and MATLAB *feels like* an introduction, suggesting a wealth of complexity and application not yet explored, and what can be achieved in an introductory setting does not look or feel like mastery to either faculty or students. While students’ communication skills and ability to integrate ethics and societal issues into their design process will also continue to develop much further than is possible in a 7-week introduction, their impression (and that of faculty, who expect not mastery but appreciation) is that they have achieved significant development already. In this sense, the "stage is set" for continued curricular development of technical and socio-technical knowledge and skills.

Anecdotal evidence also indicated that students had developed an appreciation for engineering, and engineering design, as inherently socio-technical. Student comments in response to the course included the following:

> *"I now feel like I have a moral obligation to correct inefficiencies and make technology accessible."*
>
> *"I learned that designing for myself will not actually help someone else, I need to understand them and the world they live in."*
>
> *"This class should be required for everyone at Lafayette College."*

Conclusion

In piloting an Introduction to Engineering course that introduces engineering as a socio-technical process and technology as a socio-technical system, we have sought to leverage local advantages, specifically our institution's small-college contours, commitment to liberal arts pedagogy, and administrative support for interdisciplinary activity. Yet the ways we have sought to enrich the introduction to engineering as a course suggest opportunities for educators at larger schools and traditional engineering institutes to structure an introduction with a core of socio-technical concepts.

Based on student and faculty assessment data, the course as piloted was successful in effecting the desired outcomes, particularly those most closely related to understanding engineering as a socio-technical process. The course was piloted with first-year students in the fall of 2013, so it is as yet unknown what aspects of the course students will retain and apply to subsequent coursework.

In their guise as conceptual features, the methods and contents are transferable to other institutions, even those with larger classrooms, lecture-style class meetings, and more uni-disciplinary administrative structures. For example, by beginning the undergraduate curricular path with an understanding of engineering as an inherently social and technical activity, we afforded the chance to broach political, economic, and ethical questions as part of, not ancillary to, engineering. Those issues were part of daily classroom discussions and laced into a series of assignments; they were components of design exercises and topics of debate in project debriefing; and they were in keeping with the spate of calls for engineering education reform summarized above.

Balancing the technical and non-technical content of the engineering curriculum remains a constant source of tension. With the perception (and frequent reality) that course space is a zero-sum game, every decision to add non-technical content to the engineering curriculum is a decision to reduce technical content. We have sought to work beyond that perception by developing an approach that does not force decisions between the two perceived "sides" of engineering.

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References

1. National Academy of Engineering. (2004). *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, D.C.: The National Academies Press.
2. American Society of Civil Engineers. (2008). *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*. 2nd edition. Reston, VA: American Society of Civil Engineers.
3. Lattuca, L.R., Terenzini, P.T., and Volkwein, J.F. (2006). *Engineering Change: A Study of the Impact of EC2000*. Baltimore, MD: ABET, Inc.
4. Matthewman, S. (2011). *Technology and Social Theory*. London: Palgrave MacMillan.
5. Habermas, J. (1986 [1968]). *Knowledge & Human Interest*. London: Polity Press.
6. Nye, D. (2007) *Technology Matters: Question to Live With*. Cambridge, MA: MIT Press.
7. Schatzberg, E. (2006). "Technik Comes to America: Changing Meanings of Technology Before 1930," *Technology and Culture* 47: 486-512
8. Hughes, T. (1983). *Networks of Power: Electrification in Western Society, 1880-1930*. Baltimore, MD: Johns Hopkins University Press.
9. Latour, B. (1993). *Aramis, Or the Love of Technology*. Cambridge, MA: Harvard University Press.
10. Bijker, W., Hughes, T. and Pinch, T., eds. (1987). *The Social Construction of Technology*: *New Directions in the Sociology and History of Technology*. Cambridge, MA: MIT Press.
11. MacKenzie, D. and Wajcman, J., eds. (1989). *The Social Shaping of Technology*. 2nd edition. London: Open University.
12. Bijker, W. and Law, J., eds. (1994). *Shaping Technology/Building Society: Studies in Sociotechnical Change.* Cambridge, MA: MIT Press.
13. Bijker, W. (1995). “Sociohistorical Technology Studies.” In Sheila Jasanoff, et al., eds. *Handbook of STS,* 2nd edition. Thousand Oaks, CA: Sage.
14. Smith, M. and Marx, L., eds. (1992). *Does Technology Drive History? The Dilemma of Technological Determinism*. Cambridge, MA: MIT Press.
15. Lerman, N., Oldenziel, R. and Mohun, A., eds. (2003). *Gender and Technology: A Reader*. Baltimore, MD: Johns Hopkins University Press.
16. Downey, G., Lucena, J. and Mitcham, C. (2007). “Engineering ethics and identity: Emerging initiatives in comparative perspective,” *Science and Engineering Ethics* 13: 463-487.
17. Seely, B. (2005). “Patterns in the history of engineering education reform: A brief essay.” In *Educating the Engineer of 2020* (pp. 114–30). Washington, DC: National Academy of Engineering.
18. Borrego, M. and Bernhard, J. (2011). “The Emergence of Engineering Education Research as an Internationally Connected Field of Inquiry,” *Journal of Engineering Education* 100: 14-47
19. Jesiek, B., Newswander, L. and Borrego, M. (2009). “Engineering Education Research: Discipline, Community, or Field?,” *Journal of Engineering Education* 97: 39-52.
20. Downey, G. (2009). “What is Engineering Studies For?: Dominant Practices and Scalable Scholarship.” *Engineering Studies* 1: 55-76.

21. Little, P. and Cardenas, M. (2001). "Use of 'Studio' Methods in the Introductory Engineering Design Curriculum," *Proceedings of the 2001 ASEE Conference & Exposition*.
22. Weinstein, R. D., O'Brien, J., Char, E., Yost, J. R., Muske, K. R., Fulmer, H., Wolf, J., and Koffke, W. (2006). "A Multidisciplinary, Hands-on, Freshman Engineering Team Design Project and Competition," *International Journal of Engineering Education*, 22:1023 – 1030.
23. Downey, G. (2005). "Keynote Lecture: Are Engineers Losing Control of Technology?: From 'Problem Solving' to 'Problem Definition and Solution'," *Engineering Education. Chemical Engineering Research and Design* 83(A8): 1-12.
24. Lucena, J., Schneider, J. and Leydens, J. (2010). *Engineering and Sustainable Community Development.* San Rafael, CA: Morgan and Claypool.
25. Conlon, E. (2013). "Broadening Engineering Education: Bringing the Community In," *Science and Engineering Ethics* 19:1589–1594.
26. Brown, T. (2008). "Design Thinking," *Harvard Business Review*, June, 1–10.
27. McKim, R. *Experiences in Visual Thinking,* Brooks/Cole, 1973.
28. Sawnhey, R. (2009). "Teaching Moments: A New Era for Design Education," *Fast Company* September.
29. Frank, B. Strong, D.S. and Sellens, R. (2011). "The Professional Spine: Creation of a Four Year Engineering Design and Practice Sequence," *Proceedings of the 2011 ASEE Conference & Exposition*.
30. Litzinger, T.A., Lattuca, L.R., Hadgraft, R.G., and Newstetter, W.C. (2011). "Engineering Education and the Development of Expertise," *Journal of Engineering Education*, 100: 123–150.
31. Dym, C.L., Agogino, A.M., Eris, O., Frey, D., and Leifer, L.J. (2005). "Engineering Design Thinking, Teaching, and Learning," *Journal of Engineering Education*, 94: 103–120.
32. Dym, C.L., and Little, P. (2008). *Engineering Design: A Project-Based Introduction*, John Wiley & Sons.
33. Pfatteicher, S.K.A. (2010). *Lessons Amid the Rubble.* Baltimore, MD: Johns Hopkins University Press.
34. Dick, W. and Carey, L. (1990). *The Systematic Design of Instruction*. Third Edition. New York: Harper Collins.