

An Integrative Education in Engineering and the Liberal Arts: An Institutional Case Study

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Abstract

We describe the nearly 50-year history of a unique A.B. degree program in Engineering Studies. The program was created at Lafayette College in 1970 with the goal of producing graduates who could bridge the gap between engineering and the liberal arts; its current mission is to engage students in engineering as a liberal art, recognizing the increasingly complex challenges of socio-technical systems and examining these systems through multi disciplinary perspectives. The program helps students 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.

In this paper, we describe the evolution of the program’s mission and curriculum in the context of higher education trends and societal and historical movements as well as some of the challenges faced by the program. Such a program may provide a useful case study in achieving the interdisciplinary, sociotechnical goals articulated by the NAE and others, and in broadening participation in engineering education. We consider both the transferability of our approach to other institutional contexts, and its sustainability in our own.

Introduction

Those who philosophize about the role of engineering and engineers in society have promoted a vision that goes well beyond the traditional typecasting as technical problem solvers and designers. For example, the National Academy of Engineering envisions engineers who “will remain well grounded in the basics of mathematics and science, and who will expand their vision of design through a solid grounding in the humanities, social sciences, and economics” and who will “rapidly embrace the potentialities offered by creativity, invention, and cross disciplinary fertilization to create and accommodate new fields of endeavor, including those that require openness to interdisciplinary efforts with nonengineering disciplines such as science, social science, and business” [1]. The American Society of Civil Engineers suggests that “civil engineers will serve as master builders, environmental stewards, innovators and integrators, managers of risk and uncertainty, and leaders in shaping public policy” [2]. These and other similar visions recognize that the challenges facing society today are inherently socio-technical and require collaborative, interdisciplinary solutions – solutions that can be driven by professionals who have solid grounding in engineering and the liberal arts.

Such arguments are not new. As Bruce Seely [3] observed, “[p]erhaps the most constant feature of American engineering education has been the demand for change.” The Morrill Act of 1862, which established America’s land-grant colleges, acknowledged the importance of liberal studies

in engineering education. Shirley Ann Jackson [4] noted that “[s]ince that time, there has been continuing concern that engineering education does not sufficiently incorporate liberal studies... As engineering and the technological revolution continue to transform our world, we must assure that those who steer these changes understand the totality of the human condition, and that brings us back to the liberal arts.” The chorus of calls for change has included soul-searching reports such as that by Grinter (1955) [5], which was soon overwhelmed by the urgency of Sputnik and the Space Race insisting on the primacy of purely technical competence, and Olmsted [6]. Olmsted’s 1968 ASEE Report *Liberal Learning for the Engineer* praised a few exemplary student-driven, socially contextualized curricula, spurring many technical programs to reform, for example by “humanizing” engineering, developing technical literacy in nonengineers, or trying to produce more integrative socio-technologists.

Several initiatives reflect the mid-to-late 1960s interest in educating “socio technologists” to bridge the gap between competing admiring and critical visions of technology; this period was informed by both the triumphs and the tragic consequences of WWII and Cold War technology. Wisnioski [7] calls this gap “a rift about the purposes of engineering and the nature of technology...sparked by a combination of changes in the organization, content, and scale of engineering labor, and by a trenchant critique of technology from intellectuals, activists, and everyday people.” As Mumford [8] and others provided those critiques, engineers like Samuel Florman [9] wrestled with the profession’s “existential” questions, viewed “outside” perspectives as hostile attacks, and eulogized technological optimism. The need for bridges was clear.

Lafayette College initiated its sociotechnical program of study, first known as its AB in Engineering program, in 1970. Lafayette is an undergraduate liberal arts college with strong, ABET-accredited engineering programs in mechanical, chemical, civil, and electrical engineering. The College was founded in 1826; its founding charter states that “there be established a College for the education of youth in the various branches of Science and Literature, the useful Arts, Military Science, Tactics, and Engineering.”

The first class offered at Lafayette College, in 1832, was team taught: students met in one room with two professors, one teaching Classics and the other mathematics. The curriculum expanded over the years, and in 1841 a course in civil engineering was taught. In 1866, the faculty and trustees of the College approved a new curriculum that would lead to degrees in engineering; at the time, some faculty were concerned that despite the new program’s technical and scientific rigor, it might permit students to dodge the College’s Greek and Latin requirements. Gradually, additional engineering BS programs were added to the College’s offerings.

The AB in Engineering was proposed in 1969. The rationale presented at the time was: “Society needs more liberally-educated persons with technical backgrounds. The technology to remedy or alleviate many of man’s pressing public-sector problems exists; the major obstacles are non-technical—e.g. economic, cultural, organizational, legal, political. This is true of housing, environmental pollution, food, education, and so on. These obstacles require the attention of professionals who know what technology can do, can work as or with engineers, and who have the necessary socio-political inclinations and capabilities.” This program was both a natural outgrowth of Lafayette College’s founding principles of liberal education and consistent with the trends in engineering education in the 1960s, which also impacted other institutions.

Harvey Mudd College, whose 1957 founding mission was to produce alumni who would “assume technical responsibility with an understanding of the relation of technology to the rest of society” [10], designed its engineering curricula to include one-third of students’ coursework in humanities and social science fields. In 1970, Harvey Mudd integrated bold reforms that emphasized connections across disciplinary boundaries, emphasized “the human basis of all technical problems,” and encouraged students to cultivate humility in appreciating the limitations of their knowledge: “Insist that tools take you only so far” [11]. The 1970’s WPI Plan [12] was a re-framing of Worcester Polytechnic Institute’s technical curriculum in societal context, emphasizing cooperative, project-based integrative and interdisciplinary learning. Although a proposed AB program in engineering was neither successful nor sustained, this institutional sensibility is still reflected in WPI practices at the course level (e.g. [13]) as well as larger-scale initiatives.

Since the late-1960s moment at which boundary-transgressing programs like the WPI Plan and Lafayette College’s AB in Engineering (which later became a program in Engineering Studies) curriculum were launched, disciplinary boundaries have remained strong, sometimes even being fortified on campuses. Integrative activities flourished only on the margins of traditional disciplines, rarely offered much institutional nourishment or light (e.g. [7]). Even at Harvey Mudd, the innovative interdisciplinary first-year curriculum was discontinued in 1974.

In the last decade, resurgent “interdisciplinarity” has given rise to several new programs designed to appeal to (and educate) consilient thinkers. The program in Liberal Arts and Engineering at California Polytechnic San Luis Obispo faced challenges in establishing a new hybrid course of study, but it has proved popular with students who find themselves both fulfilled and employable [14]. The University of Utah’s program in Entertainment Arts and Engineering, and Arizona State’s School of Arts, Media + Engineering, are each described as “gaining traction” [15]. Another intriguing new program is the integrated CS + X joint major at Stanford University, “an experiment in learning” starting in Fall 2014, with the stated goal “to give Stanford students the chance to become a new type of engineer and a new type of humanist” [16]. Smith College added an AB in Engineering Arts to its Picker Engineering Program, for students “who want to better understand the engineer’s role in service to humanity, and who do not intend to pursue professional practice as engineers” [17]. The University of Virginia houses its outstanding Science, Technology, and Society (STS) program within the College of Engineering, and requires that engineering students complete five STS classes.

The joint National Academies of Sciences, Engineering, and Medicine launched a working group in 2015 [18] and published its findings and recommendations advocating for greater interdisciplinary integration in 2018 [19]. Also in 2015, a workshop was convened by the National Academy of Engineering and National Science Foundation to share and discuss current practices as well as potential curricular redesign concepts to integrate liberal arts and engineering content ([20]-[21]). The workshop shone light on a wide range of activities and perspectives. Several existing and well-tested prototypes for the proposed redesign challenge could be discussed and evaluated. Gary Downey has published both the provocation for this particular workshop, as well as many participants’ contributions and responses, in a special issue of the journal *Engineering Studies* (Vol. 7(2)), including a brief description of the integrative program

in Engineering Studies at Lafayette College [22]. Common themes included uncertain student prospects following integrative degree programs; the diverse range of institutional obstacles to integration; and the need for engineers both to become broadly educated and to recognize the limits of their expertise, and when to reach out to other experts (e.g. [23]).

Lafayette College's AB program in Engineering Studies meets societally articulated needs for engineering education both *then*—at the time of its founding in 1970—and *now*, almost uncannily. Our program is designed to educate sociotechnical, integrated, technological citizens. In our institutional context this program has not replaced traditional BS engineering programs, but has coexisted with and complemented them. The Engineering Studies Program provides an opportunity for students to integrate engineering and the liberal arts, to become broadly educated sociotechnical citizens, and to pursue their own interests within its flexible curriculum, guided by thoughtful academic advising from the program's faculty. This paper describes the details and evolution of our program's curriculum, the obstacles it has encountered, trajectories of its graduates, and opportunities for its transferability and sustainability.

Evolution of the Program

The AB in Engineering program at Lafayette was envisioned as a bridge between engineering and the liberal arts, educating “sociotechnical engineers.” Since its establishment in 1970, it has experienced significant restructuring (in 1990), subsequent modifications, and a major 2008 overhaul in focus and curriculum; yet, the core vision and motivation remain. The AB in Engineering began as a liberal arts degree that included science, math, and engineering classes as major requirements. The program initially was designed by two engineering faculty members, both with backgrounds in traditional engineering disciplines and interests in history of technology; the program introduced students to a broad conception of engineering.

As shown in Figure 1, the program began with a small number of majors and grew quickly. Enrollments in the program have fluctuated considerably over its almost 50-year history, with a mean of between 17 and 18 students per class year. Figure 2 shows that these trends largely follow the overall enrollments in engineering programs at Lafayette, with increased shares of AB Engineering degrees awarded in the mid-1980s and 2000s.

In the early 1980s, preceding and coincident with these large enrollments, the college's first year Introduction to Engineering course was taught by one of the two founders of the AB in Engineering program, a charismatic and dynamic professor. This professor retired in 1988, and at the same time the Introduction to Engineering course was replaced by a sophomore level course on engineering professionalism and ethics. That students were no longer being introduced to the major during their first year by an enthusiastic faculty member in a required class may have contributed to the reduced number of graduates in the early 1990s.

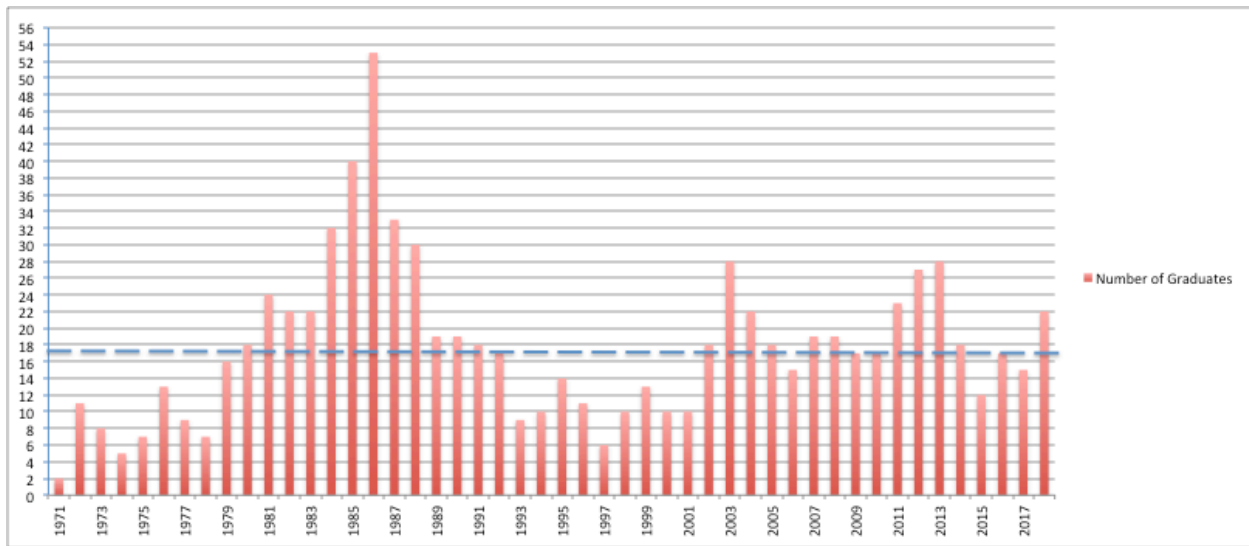


Figure 1. AB Engineering degrees awarded by year. The dashed line represents the mean from 1971 through 2018.

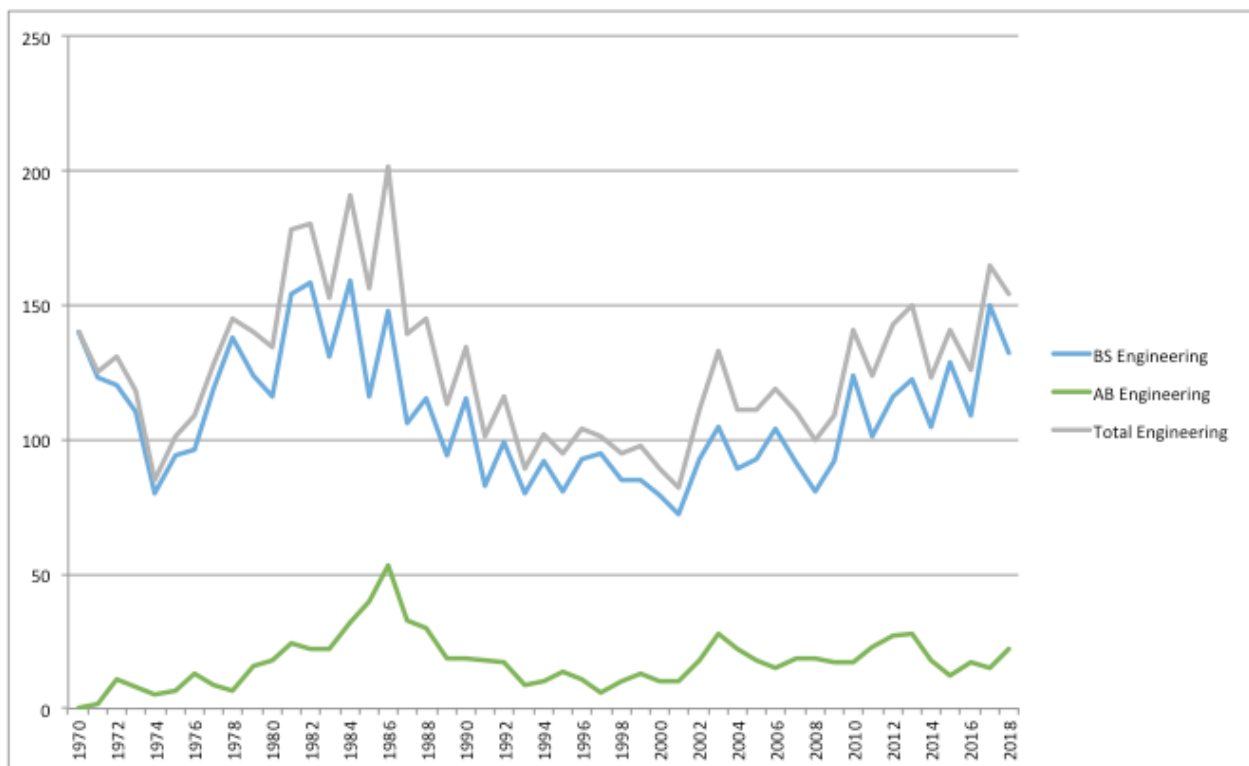


Figure 2. Numbers of engineering degrees awarded from the beginning of the AB in Engineering degree to present.

One challenge for this program has been that the limited human resources dedicated to the program constrained its mission and scope. In the mid-1980s, the College’s Engineering Science Department (which did not house a major but included dedicated faculty and foundational courses common to all engineering disciplines) was dissolved, and the Metallurgical Engineering

degree discontinued. Faculty members from both were incorporated into other departments on campus. The two faculty lines associated with the AB in Engineering degree and the courses for which they were responsible were moved from the Engineering Science Department to the Department of Civil Engineering.

In 1986, a new faculty member with expertise in Science, Technology, and Society was hired. This faculty member chaired the program for one year (1988-1989), after which a more established faculty member from another engineering department assumed the position. These two faculty members had divergent visions for the major, with the more junior member advocating for additional curricular requirements in the first and second years, a required specialty area in policy or management, and a required capstone; the more senior member advocated for requiring international experience prior to graduation. A joint degree program in which students can earn a BS with a major in one of the engineering disciplines and an AB in International Studies was established, and thus the former approach was pursued for the requirements for the AB Engineering degree.

During the 1990s, a new faculty member was hired to teach economics- and management-related courses, and the STS/policy-oriented faculty member was denied tenure. A subsequent policy-oriented hire also left after several years, and thus the 1990s were a period of flux for the program in terms of staffing and curriculum. This upheaval appears to be reflected in the lower numbers of degrees awarded during this time period. Furthermore, half of one of the two faculty lines that had been dedicated to the AB in Engineering program was absorbed by the Department of Civil and Environmental Engineering, leaving the program with just 1.5 faculty lines.

In 2002, a new faculty member with expertise in engineering and public policy, and a background in civil engineering, was hired to fill the single full faculty line. The background in civil engineering was important at the time because the program was still housed (and thus program faculty evaluated, tenured and promoted) within the Department of Civil and Environmental Engineering. This new faculty member assumed the program chair position and, with the continuing faculty member with a 0.5 appointment in the program, moved to establish the program as an independent entity at Lafayette.

With the program's move toward independence came the opportunity to re-envision its identity and mission. A Strategic Plan developed for the program in Spring 2007 stated that “the degree is designed to *provide students with an inter disciplinary undergraduate curriculum that prepares them to successfully address the challenges of an increasingly complex, technical world.* This is done by ensuring that students have a strong base in mathematics and science, fundamental engineering skills that apply across technological systems, full participation in the College's Common Course of Study, and a required three-course **inter-disciplinary core of engineering economics and management, engineering and public policy, and engineering and society.**” Figure 3 shows the program mission and learning outcomes for majors at that time.

One important strategic change was the renaming of the program as **Engineering Studies**. This made clearer the program's resemblance to the “area studies” fields of social sciences, such as gender studies, ethnic and cultural studies, and science & technology studies, and its ability to contextualize and critique its technical and engineering coursework [24]. This also served to

distinguish the program more clearly from Lafayette’s BS engineering degree programs, telegraphing that its graduates would possess distinct knowledge, methods, and skills from their BS peers. The program’s identity as a bridge between engineering and traditional liberal arts was clarified by its new name.

In 2010, the program changed chairs, and a search was conducted to fill a new faculty line that the program had requested successfully. During this search process, the faculty member who held the full line in Engineering Studies decided to pursue an opportunity at another institution. Thus, two new faculty members were hired – each entirely dedicated to the Engineering Studies Program – to begin in the Fall 2011 and Spring 2012 semesters, respectively. This brought the total full-time staffing of the program to 2.5 faculty lines – the senior faculty member whose appointment is split between Civil and Environmental Engineering and Engineering Studies, and the two newer faculty members whose lines are both fully within the Engineering Studies Program.

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| <p style="text-align: center;">Mission</p> <p style="text-align: center;"><i>To provide a select set of curricular opportunities that allows a diverse group of students to study engineering within the context of a broad liberal arts education while benefiting from an exclusively undergraduate setting that enhances student-faculty relationships.</i></p> <p style="text-align: center;">Learning Outcomes for Majors</p> <ul style="list-style-type: none">• Apply fundamental scientific, mathematical, and engineering concepts and problem-solving strategies to technical problems.• Apply fundamental policy and economic frameworks to technical problems.• Understand the broader societal context within which technical problems exist.• Appreciate the ethical and global aspects of technical problems.• Communicate technical issues effectively to a variety of audiences using graphical, verbal, and written techniques.• Demonstrate effective life-long learning, and multidisciplinary teamwork skills. |
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Figure 3. Mission and learning outcomes for the AB in Engineering Program c. 2007.

In the Spring of 2011, our College’s Engineering Division underwent an external review. The resulting report noted that the AB Engineering Studies degree “is an attractive option for students to truly capitalize on the integration of engineering and the liberal arts.” The reviewers further reported that they had “heard from employers who were very enthusiastic about the AB engineers that they hired.” [25]

In Spring of 2012, the Engineering Studies program underwent its own external review. At that point, the mission statement was under revision, and the draft version was “To provide a rigorous liberal arts curriculum built on an engineering foundation that prepares graduates to effectively address society’s increasingly complex, multi-disciplinary challenges. Graduates gain expertise in examining the place of engineering and technology in society, with interdisciplinary skills to

lead public technology debates around policy, management, economic, and environmental issues.” The mission statement and learning outcomes for majors were subsequently revised as shown in Figure 4.

Current requirements for the major, in addition to our College’s common course of study, include:

- Seven foundation courses (Introduction to Engineering, three semesters of calculus, and one semester each of introductory chemistry, physics, and economics)
- Three core Engineering Studies courses (Engineering and Public Policy, Engineering Economics and Management, and Engineering and Society), and
- Nine elective courses, which include
 - Three 200-level engineering courses, two of which should be traditional engineering problem solving courses such as Statics or Circuits,
 - Three 300- or 400-level engineering courses,
 - One additional upper-level math course,
 - One additional science course, and
 - One additional science, computer science, or upper level math course.

Mission (revised 3/30/15)

The Engineering Studies Program engages students in engineering as a liberal art, recognizing the increasingly complex challenges of engineering in the larger framework of socio-technical systems and examining these systems through multi-disciplinary perspectives.

Learning Outcomes for Majors

1. Demonstrate an understanding of engineering as a socio-technical activity;
2. Apply multi-disciplinary perspectives to understand, formulate, analyze, and develop sustainable solutions for complex problems;
3. Demonstrate an understanding of ethical leadership and professional responsibility;
4. Integrate multiple and diverse perspectives in defining and solving engineering problems in cultural context;
5. Work effectively in teams; and
6. Explain and communicate effectively solutions using visual, oral and written techniques to diverse audiences.

Figure 4. Current mission and learning outcomes for the Engineering Studies Program.

The current curriculum, which casts engineering as a socio-technical system [26], requires students to complete the Engineering and Public Policy and Engineering Economics and Management courses no later than the end of the junior year as prerequisites to the capstone course on Engineering and Society in the fall of the senior year. In the capstone course, students are asked explicitly to reflect on the nature of their education and to synthesize not only

knowledge and skills from the required Engineering Studies courses but also from their other courses – math, science, engineering, social science, and humanities. The sequencing requires students to be intentional about their choice of major and enables students to build a cohort within the major.

The Engineering Studies Program works with other departments and programs to teach and provide opportunities for students across administrative boundaries. For example,

- the Engineering and Public Policy course is cross-listed as Introduction to Policy Studies, a requirement for the AB Policy Studies major;
- an Engineering Studies faculty member has taught a course on the history of technology in the History Department;
- an Engineering Studies faculty member has co-taught the AB Environmental Studies major capstone course; and
- an Engineering Studies faculty member has advised and co-advised student research in the Department of Mechanical Engineering.

In practice, institutional administrative practices as well as departmental/program and individual interests have influenced the ease with which these partnerships have been facilitated and whether they have been sustainable in a reciprocal way.

The additional faculty line added in the 2011-2012 academic year has enabled the program to expand its course offerings as well as to increase cooperation with other departments and programs. For the first time in recent history, an Engineering Studies faculty member has taught in the college's First Year Seminar program; this undoubtedly has had positive effects on enrollment as students across campus (not just within engineering) are introduced to the program and its faculty. The current faculty has introduced several new elective courses, including:

- Power! Energy Technologies in Context,
- Energy Technology and the Modern World,
- Historical Studies in Engineering and Society, and
- Technology and Nature.

The first of these is designed to fulfill common course of study requirements for students who are not engineering majors, while the second is geared toward students with a technical background. The last is cross-listed as an Environmental Studies course. All four have no or minimal pre-requisites, making them available to all students on campus.

In addition to courses taught by full-time, tenured or tenure-track faculty members, the Engineering Studies Program has actively employed adjunct faculty members with particular areas of expertise to expand the breadth of the program's course offerings. For example, Architectural Engineering was taught first by a local architect and then by our campus architect. A course on Building the High-Tech Start-up has been taught by the manager of a local technology incubator. And for a number of years, an Internship course was facilitated by a local engineer with a lengthy career in a prominent firm. These adjunct faculty members have broadened and enriched the courses available not only to Engineering Studies majors but to all students on campus.

The program is thriving, yet challenges remain. Our campus culture professes to value "integration of engineering and the liberal arts," but as a campus, we continue to struggle with

what that means in practice, and what role the Engineering Studies Program should play in creating and sustaining that culture. Too often, the program has been understood in terms of what it is *not*, and the ways it diverges from our ABET-accredited BS majors, rather than for the unique combination of disciplinary methods it combines. This was damaging to the identity of our AB students. Worryingly, the program's existence can sometimes permit other College programs to abdicate their own potential contributions to interdisciplinary integration. We understand from both the history of engineering education, and history itself, that a single "bridge" is insufficient. The program continues to work hard to communicate effectively with prospective and current students, their families, our faculty colleagues, and campus administrators about the role of and opportunities provided by the program.

Student Experience and Outcomes

The Engineering Studies major requirements incorporate substantial student flexibility. Of the 32 courses required for graduation from Lafayette College, only eleven are identified as specific courses required for the AB Engineering degree. Of these, ten fulfill requirements for the major and one is the First Year Seminar required for all students at our college. The additional nine course requirements for the major all contain flexibility to choose among two or more courses to fulfill the requirement. As a result, students' paths to completion of the AB Engineering degree and their career paths after graduation may be quite different from one another. Table 1 provides some examples of recent graduates' choices, illustrating the different directions in which students focused their coursework. Helping students structure this flexibility in the service of their interests and goals requires substantial hands-on advising.

At Lafayette, students who earn AB Engineering degrees double major at approximately the same rate as students who are not engineering majors (26.0% and 26.2%, respectively, from 1996-2018). Both of these are substantially higher than the 8% rate for BS Engineering graduates. This is not surprising given the rigidity of the BS Engineering major requirements; our four BS engineering programs all require 36 courses, of which 23-25 are prescribed. The flexibility in the Engineering Studies major has led to double majors in fields as diverse as Art, Asian Studies, Economics, English, Environmental Studies, Geology, German, Film and Media Studies, International Affairs, and Psychology. Anecdotally, some of these students have pursued the double major to facilitate particular career goals (for example, a double major in Art as preparation for Architecture School or a double major in Economics as preparation for a career in finance), while others have pursued an intellectual interest with no clear, direct connection to the fields in which they aspired to work. Both of these approaches are typical of liberal arts majors, but less typical of students pursuing a BS in Engineering at Lafayette, most of whom go on to at least initial positions in engineering firms.

Table 1. Selected course lists at graduation for Engineering Studies majors.
 ES: Engineering Science, EGRS: Engineering Studies, CE: Civil Engineering,
 ChE: Chemical Engineering, ME: Mechanical Engineering

| | Math | Science | Engineering | Humanities | Social Science |
|-------------------------|--|--|---|---|---|
| Required | Calculus I Calculus II Calculus III Elective Elective OR | Chemistry I Physics I Elective Elective | Introduction to Engineering (ES) Engineering Economics & Management (EGRS) Engineering & Public Policy (EGRS) Engineering & Society (EGRS) 6 Electives | Elective | Principles of Economics 2 Electives |
| Minimum Required | 4 or 5 | 3 or 4 | | 10 | 1 |
| Student A | Differential Equations | Chemistry Geology Psychology | Statics (ES) Strength of Materials (ES) Manufacturing and Design (ME) Energy Technology & the Modern World (EGRS) Engineering Management (EGRS) Historical Studies in Engineering & Society (EGRS) Sustainable Solutions (EGRS) | English (13 courses, including thesis) Latin Theater Womens & Gender Studies | Government & Law History |
| Total | 4 | 4 | 5 | 11 | 16 |
| Student B | Linear Algebra | Computer Science Psychology | Nature of Materials (ES) Statics (ES) Fluid Mechanics (CE) Water Quality (CE) Water Resources Engineering (CE) Sustainable Solutions (EGRS) Technology and Nature (EGRS) | Japanese (4 courses) Religious Studies | Anthropology & Sociology (6 courses) Asian Studies (2 courses) Government & Law History (2 courses) Interdisciplinary |
| Total | 4 | 4 | 4 | 11 | 5 |
| Student C | Probability & Statistics | Chemistry (2 courses) Geology (13 courses) | Statics (ES) Environmental Engineering (CE) Environmental Geophysics (CE) Land Development & Surveying (CE) Architectural Engineering (EGRS) Sustainable Solutions (EGRS) | Film & Media Studies Religious Studies Spanish | Africana Studies Anthropology & Sociology Education Interdisciplinary |
| Total | 4 | 4 | 17 | 10 | 3 |
| Student D | Differential Equations Probability & Statistics | Biology (3 courses) Chemistry (2 courses) | Nature of Materials (ES) Statics (ES) Strength of Materials (ES) Material & Energy Balances (ChE) Dynamics (ME) Fluid Mechanics (ME) Heat Transfer (ME) Thermodynamics (ME) Energy Technology & the Modern World (EGRS) Engineering Management (EGRS) Historical Studies in Engineering & Society (EGRS) Sustainable Solutions (EGRS) A Taste of Italian Engineering (EGRS) Thesis (EGRS, 2 courses) | Philosophy Womens & Gender Studies | Government & Law History |
| Total | 5 | 5 | 7 | 15 | 2 |

In their Capstone experience, Engineering Studies majors are asked to reflect on their paths through the major and how they have achieved the learning outcomes for the major. Some examples of student responses, excerpted from these autobiographical essays, include:

- “One of the most valuable skills that [the program] has taught me is this skill of asking “why” not “how.” Asking “how” typically results in a methodological solution, rather than a solution that conveys understanding. Asking “why” instead of “how” has resulted in a better understanding of the reasoning behind things, as well as an increased awareness of the methodology.”
- “I see that engineering is creating. It’s a way to make art come to life while solving society’s problems. It’s a way to blend creativity and practicality. I see myself not as simply an engineer, or an artist, but as a cross, or better yet a blend, between the two. Moving forward, I hope to facilitate in bridging the gap between art and engineering. ... from my time at Lafayette, I see how they can be combined to create better resolutions to the world's problems....”
- “Listening, writing, debating, and speaking help engineers recognize and discuss what the wants and needs are of the community and how to help solve them.”
- “I developed a greater understanding for human interactions with new technology and realized the different levels of technological proficiency throughout the world, thus, helping me to understand the implications public policy has on the world when dealing with technology in relation to products and the environment.”
- “I gained an understanding of the impact the built world and urban infrastructure (designed predominantly by civil and environmental engineers) had on the social ecosystems which they encompassed. Rather than a drive to help those in ‘need’ ... I had now developed a consciousness for the positive and negative impacts of engineering systems and design on economies, cities, governments, and societies.”
- “I learned that solving ... problems, especially the technical problem solving that is worshiped in traditional engineering courses, is the easiest part; having the patience to deeply understand a situation is actually the hardest aspect of what engineers should be doing.”
- “Through the wide variety of classes I have taken, I have transformed into a person who approaches all through an interdisciplinary framework. I have learned to bring technical expertise such as the importance of qualitative and visual data to group projects in order to better prove our points. I have also learned to bring an anthropological or environmentalist mindset to other group projects in a room filled with engineers.”
- “For many engineers a project is successful and complete if it is installed, and carries out its intended purpose; however, an engineering studies student is taught that a project is successful if it carries out a purpose which has a positive impact on a community, and a project is only complete once it has proven to be sustainable in a community for an extended period of time.”
- “At the end of my summer internship I received feedback that I took great initiative and was an active learner, which are the most important qualities that employers look for when hiring recent undergraduates. As Engineering Studies students, the habit of always questioning and analyzing the information we are given based on multiple contexts is engrained in us, and that mindset contributes to success in every aspect of one’s life.”
- “Engineering Studies attempts to bridge the gap between the objective and the subjective. There can’t be a world of simply objective thinkers, there are too many worldly factors that have to be considered. This includes economic, environmental, cultural, societal, and political effects that are brought forth by scientific or engineering feats. The mindset that the Engineering Studies major creates is that life is a balance of interests, and [before]

disrupting this balance, one should consider the change and its externalities in the first place. This mindset requires critical thinking, communication, and analytical skills as well the background in math and science....

- “I have developed my own definition of Engineering Studies. Engineering Studies is a program that prepares students to contribute towards the solutions and implementations of the complex problems that the world is currently facing. It teaches students non-technical skills such as how to think about problems holistically, incorporate different contexts, communicate with others, and lead fellow professionals.”

An examination of self-reported placement data from 2001-present, provided by our college’s career center, reveals a wide variety of companies and graduate programs as well as job titles. The data is challenging to synthesize because job titles can reflect quite different functions in different industries, and employers are not categorized into industries. Nonetheless, we can see the core of the Engineering Studies Program reflected in the data. Of the 213 students who reported about their first job during that time period, 82 began in positions with the word “engineer” in the title, 47 (including some of the 82) had titles that included the words “project manager” or “project engineer,” and 26 were beginning as an “analyst” of one sort or another. A search of employer names reveals that of the 160 distinct companies that hired graduating students with AB Engineering degrees, 17 company names include the word “construction,” and eight include the word “engineering.” The most common employers were Clark Construction (12), IBM (8), and Turner Construction (6). Thirty-two students reported entering graduate or professional school immediately after graduation. Of these, the most common programs were in engineering management and architecture. Other graduate programs included city and regional planning, divinity, economics, energy systems engineering, environmental management, and international development; two attended medical school, and one attended law school. It should be noted that this only captures students who entered these programs immediate after graduation from Lafayette; we know that more students return to formal education as they navigate their careers.

Engineering Studies graduates are more diverse in terms of gender than are Lafayette’s graduates with BS degrees in engineering, and they are more diverse in terms of ethnicity than both those with BS Engineering degrees and students with degrees in disciplines other than engineering (Figures 5-7). Clearly, the Engineering Studies Program is a place where women and students of color feel comfortable. However, given the challenges in messaging that historically have surrounded the program (e.g., a perception that the degree is less “rigorous” and therefore less “valuable” than a BS in engineering), there is a simultaneous concern about ghettoization – that is, a perception that because the program is more attractive to women and students of color it must be less valuable [27], e.g.. Anecdotally, this concern does not seem to be voiced commonly by students, but it is a concern of faculty members. A related concern is that when enrollment numbers are reported for all of the Engineering Division, the relative overrepresentation of women and students of color in Engineering Studies can mask the underrepresentation in other departments.

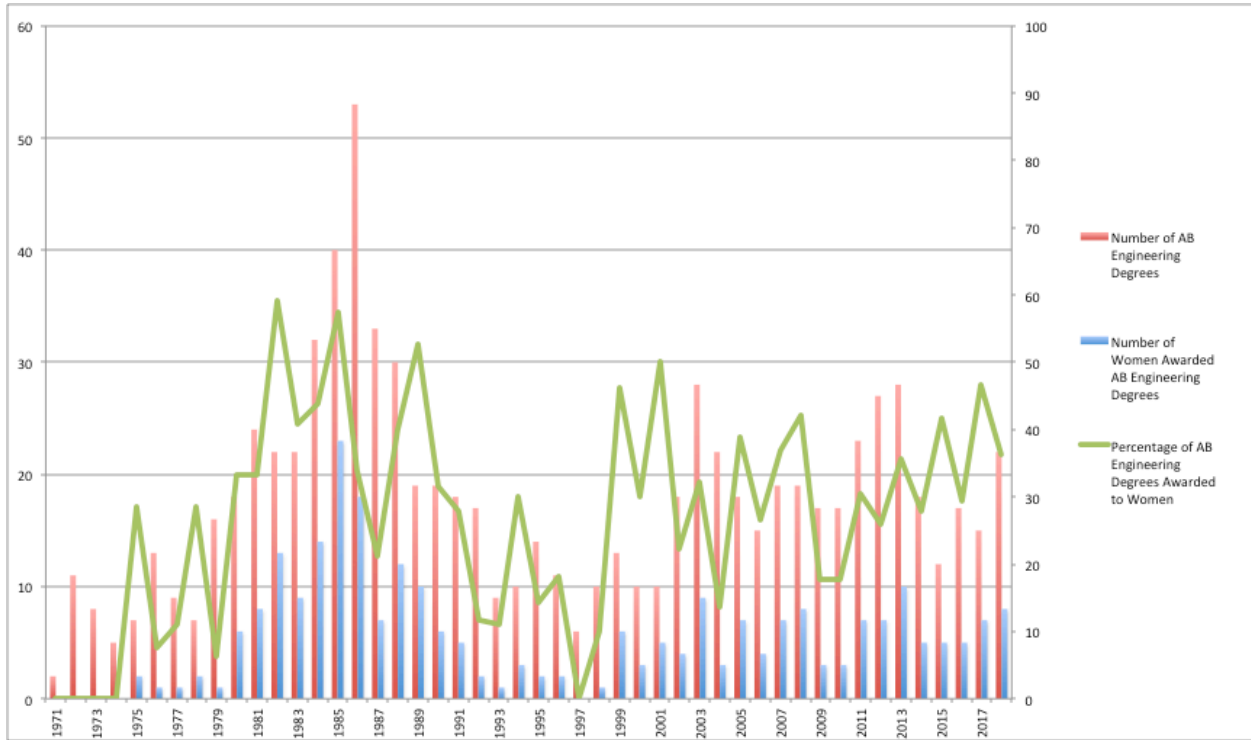


Figure 5. AB Engineering degrees earned by women over program history.

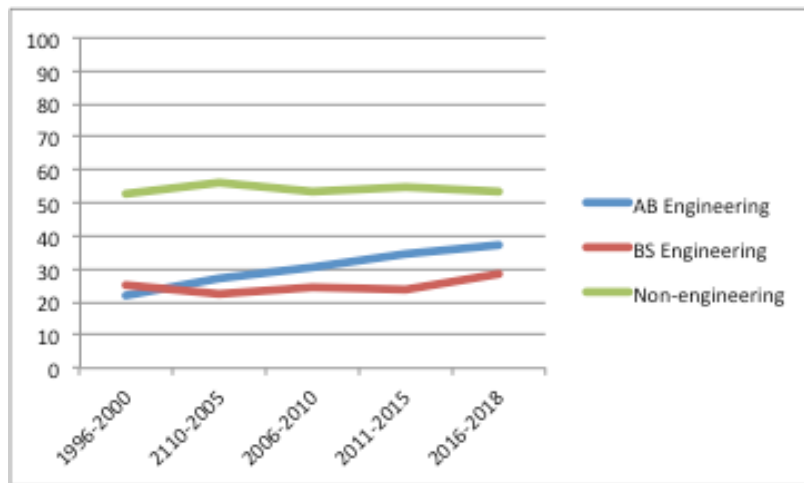


Figure 6. Percentage of women among Lafayette College degree awardees from 1996-2018.

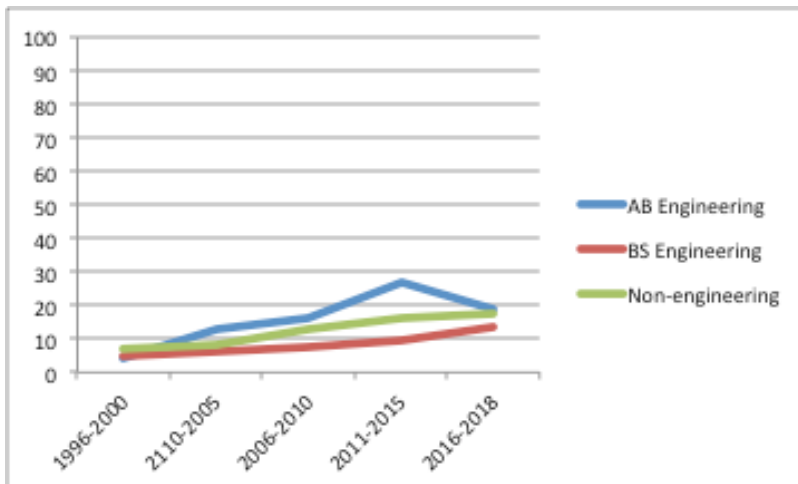


Figure 7. Percentage of domestic students of color among degree awardees from 1996-2018.

Sustainability and Transferability

After nearly fifty years, we are in a position to reflect on the past of Lafayette College's degree program in Engineering Studies and to anticipate its future. We can envision a growing menu of classes for our majors and for all students on our campus. We hope that the strategic significance of the program as a bridge between engineering and liberal arts will be reflected in continued growth in the number of faculty involved in teaching classes and working with our students.

We might ask ourselves whether a long term goal should be the obsolescence of programs like this one, as our BS engineering programs integrate increasing emphases on ethics, social and cultural contextualization, and other hallmarks of our Engineering Studies program. It is the authors' contention that all engineering classes ought to integrate historical context and ethics, and that all engineering programs ought to be offering courses to support non-engineering students. The existence of a program specializing in integration risks enabling others to abdicate their own responsibility for the integration of engineering and liberal arts, whether that might be introducing socio-cultural-historical-or-other context into technical courses, or offering expertise to others outside one's home discipline. Similarly, the appeal of an interdisciplinary program in Engineering Studies to a more diverse student body than some traditional BS majors risks permitting other programs to be complacent about their own demographics and inclusivity.

The Engineering Studies program's service to and role in the greater Lafayette College and local communities includes facilitating interdisciplinary dialogues. Two examples include the Forum on Technology and the Liberal Arts, which is chiefly organized by an Engineering Studies professor; and a symposium on fracking that was co-organized by Engineering Studies, English, and Environmental Studies and engaged both the College and larger region in complex sociotechnical discussions. In facilitating these conversations, faculty members are modeling the sort of technological citizenship and interdisciplinary leadership roles we anticipate for the program's graduates.

Those seeking to foster similar interdisciplinary connections and develop integrative curricula at other institutions may encounter challenges unique to their own institutional contexts. One key lesson of our program's mission and curricular evolutions is the importance of being clear about what will distinguish its graduates: what particular methods or mindsets will they be known for, and excel in? A broad program need not be shallow.

Since it is rare for an institution to fully staff a new major program on its launch date, it is likely that limited human resources will constrain such a program's scope and development. In our case, the small number of faculty committed to Engineering Studies has meant that those faculty's interests have driven the curriculum in particular directions (toward policy and engineering economics originally, and more recently toward issues of energy and environment). Whether such an initiative is being pursued by existing or new faculty, desired breadth and areas of focus should be considered in the selection of faculty partners. Another challenge related to faculty is the challenge of joint and shared appointments, and initiatives housed within existing programs: this gives faculty a multitude of institutional "hoops" to jump through to earn reappointment, tenure, and promotion, and it means that their interdisciplinary work may not be highly valued by those evaluating them. Explicitly communicating mutual expectations in memoranda of understanding for faculty involved in interdisciplinary initiatives such as Lafayette's Engineering Studies program is now understood to be good institutional practice.

Our program began with an inspiring vision, but without a detailed plan for implementation. As a result, its early evolution was somewhat ad hoc. If faculty and administrators had begun with a stronger sense of what they wanted the program to look like and achieve, the path might have been straighter. Modeling that considers the expected range of student interest in such a program, anticipates the impact on other programs, and plans for future development and growth would be a valuable guide for such a program. Curricula are nonunique solutions to the problem of what concepts, methods, and values students need to learn, and our focus on sociotechnical thinking both permits an even wider space of possible solutions *and* requires vigilant continuous attention to remain relevant.

The courses and curricula developed for Lafayette's Engineering Studies program have been innovative, interdisciplinary, and effective in helping students and faculty negotiate with sociotechnical systems and thinking. We have found team teaching and cross-listing of courses (e.g. in Engineering Studies and Policy Studies) to be useful ways to model and signal the interdisciplinary dialogue and connections involved in our major. Even for courses that are not team taught, the involvement of multiple programs in developing syllabi and course expectations, as well as the contributions of faculty from across the College in the program's advisory committee, ensure that multiple disciplinary perspectives are represented in our classes. We also strongly encourage the scaffolding of sociotechnical and STS concepts in a multi-course sequence, to enable students to progressively develop a more sophisticated understanding and skillset.

The societal and sociotechnical needs to which our program's creation responded to are still—perhaps even more—relevant today. Many of our most vexing sociotechnical challenges, sometimes described as "Grand" challenges, from slowing or mitigating climate change to considering the accessibility, inclusivity, and impact of new technologies, exist in the spaces

between traditional disciplines—meaningfully addressing these challenges will require the artful combination of multiple approaches and methods. A “bridge” remains an apt metaphor for our Engineering Studies program, though we hope not to be the only such bridge at our College or elsewhere. Developing students’ ability to synthesize the methods and mindsets of multiple disciplines, to possess multiple fluencies, is the work of liberal education.

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References

- [1] National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*. The National Academies Press: Washington, D.C, 2004.
- [2] American Society of Civil Engineers, *The Vision for Civil Engineering in 2025*. American Society of Civil Engineers: Reston, VA, 2007.
- [3] B. Seely, “Other Re-engineering of Engineering Education,” *Journal of Engineering Education*, Vol. 88(3), pp. 285-294, 1999.
- [4] S.A. Jackson, “Engineering and the Liberal Arts,” Smith College, 2001.
- [5] L.E. Grinter, “Summary of the report on evaluation of engineering education,” *Journal of Engineering Education*. pp.25-60, 1955.
- [6] S.P. Olmsted, S.P. *Liberal Learning for the Engineer*. American Society for Engineering Education, 1968
- [7] M. Wisnioski, *Engineers for Change*. Cambridge: MIT Press, 2012.
- [8] L. Mumford, *The Myth of the Machine: Technics and Human Development*, Harcourt, Brace and World: New York, 1967.
- [9] S.C. Florman, *The Existential Pleasures of Engineering* St. Martin’s Press: New York, 1976.
- [10] Harvey Mudd College, *Bulletin, 1958-1959* (Claremont, CA: Harvey Mudd College), 1958.
- [11] Harvey Mudd College, *Bulletin, 1972-1973* (Claremont, CA: Harvey Mudd College), 1972.
- [12] W.R. Grogan and R.F. Vaz, “The seven steps to sustainable change at WPI” *Liberal Education* Vol. 89: 1, pp. 32–35, 2003.
- [13] J. Rudolph, “Reaction: pushing the boundaries of engineering education,” *Engineering Studies* Vol. 7(2), 2015. DOI: 10.1080/19378629.2015.1062497
- [14] D.D. Gillette, E. Lowham, and M. Haungs, “When the hurly-burly's done, of battles lost and won: How a hybrid program of study emerged from the toil and trouble of stirring liberal arts into an engineering cauldron at a public polytechnic,” *Engineering Studies*, Vol. 6(2), pp. 108-129, 2014.
- [15] A. Daniel, “Full steam ahead,” *American Society for Engineering Education Prism (March)*, pp. 34-36, 2015.
- [16] E. Roberts, “Joint majors: CS + X,” Stanford University, 2014. Retrieved from: <https://undergrad.stanford.edu/academic-planning/majors-minors/joint-majors-csx>.

- [17] B. Mikic and A. Guswa, "Engineering Meaning: how Smith engineers embrace a liberal education," *Union College Symposium on Engineering and Liberal Education*, Schenectady, NY, 2014.
- [18] H. Stewart-Gambino and J.S. Rossmann, "Often Asserted, Rarely Measured: The Value of Integrating Humanities, STEM, and Arts in Undergraduate Learning." National Academies of Sciences, Engineering and Medicine, 2015.
- [19] National Academies of Sciences, Engineering, and Medicine, *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree*. Washington, DC: The National Academies Press, 2018. <https://doi.org/10.17226/24988>.
- [20] L. Bucciarelli and D. Drew, "Liberal studies in engineering – a design plan," *Engineering Studies* Vol. 7(2). 2015. DOI: 10.1080/19378629.2015.1077253.
- [21] L. Bucciarelli, D. Drew, and S. Tobias, "Liberal studies in engineering - Workshop Report," Washington DC. 2015. Retrieved from http://dspace.mit.edu/bitstream/handle/1721.1/96672/Workshop_Report_final.pdf.
- [22] J.S. Rossmann and K.L. Sanford Bernhardt, "Reaction: Sociotechnical engineering is one facet of prismatic liberal education," *Engineering Studies* Vol. 7(2), 2015. DOI: 10.1080/19378629.2015.1062505
- [23] J.D. Klein, "Comment: teaching and learning limits in engineering education," *Engineering Studies* Vol. 7(2), 2015. DOI 10.1080/19378629.2015.1062494
- [24] G.L. Downey, "What is engineering studies for? Dominant practices and scalable scholarship," *Engineering Studies*, Vol. 1(1), pp. 55-76, 2009.
- [25] External Review of Lafayette College Engineering Division, 2011.
- [26] B. Cohen, K. Sanford Bernhardt, and J.S. Rossmann, "Introducing engineering as a socio-technical process," Proceedings from 2014 ASEE: *Annual Conference & Exposition*. Indianapolis, IN: American Society for Engineering Education, 2014.
- [27] C.E. Foor and S.E. Walden, "'Imaginary Engineering' or 'Re-imagined Engineering: Negotiating Gendered Identities in the Borderlands of a College of Engineering,'" *NWSA Journal*, Vol. 21(2), pp. 41-64, 2009.