AC 2007-1516: CREATIVE, CONTEXTUAL, AND ENGAGED: ARE WOMEN THE ENGINEERS OF 2020?

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Abstract

This paper discusses findings from a multi-institutional longitudinal study of the engineering student experience. Data from multiple research methods are discussed regarding qualitative differences in contextual awareness and student engagement of engineering students, concentrating on the differences between men and women enrolled as engineering students at four institutions. Data from this study suggest that women are more contextually aware and highly engaged than men, and that women may have certain attributes that fulfill both the criteria for *Engineer of 2020* and current ABET accreditation standards. The authors argue that providing opportunities to foster contextual awareness and student engagement should result in greater satisfaction for all students.

Background

Educators, professionals and policy-makers alike recognize that contemporary engineering must be studied and practiced in context. The National Academy of Engineering (NAE) envisions an "Engineer of 2020" who demonstrates "dynamism, agility, resilience, and flexibility" to design for an uncertain and rapidly changing world.[1] Contextual conditions like a fragile global economy, increased mobility of jobs and workers, rapid development of information and communication technologies, growing calls for social responsibility,[2] and rising complexity of engineered products[3] all warrant engineering students' development of skills with which to situate their technical work. Furthermore, the increasingly diverse engineering workforce and marketplace require "cultural competence"; that is, a willingness and ability to consider culture in engineering problem-solving.[4] This growing recognition of the need for contextual awareness makes the ABET learning outcomes that speak to context particularly relevant. Among ABET's technical and professional learning outcomes are both the ability to design within realistic contextual constraints and an understanding of the impact of engineering solutions within a global and societal context.[5]

Research has demonstrated that when given the opportunity to learn in context (e.g. through service learning projects or study abroad), students become better engineering problem-solvers with better communication skills and improved abilities to work with diverse people.[2] Well-designed project-based learning (PBL) that provides students the opportunity to apply abstract concepts to hands-on activities in context not only leads to knowledge acquisition, but also has been shown to increase engineering-student retention rates.[3] Additionally, other behaviors indicate that students are operating contextually while in college. The National Survey of Student Engagement (NSSE) annually surveys college students "to assess the extent to which they engage in educational practices associated with high levels of learning and development."[6] Distinguishing between what Boyer[7] once termed "competence" and "commitment," the NSSE shifts the focus from outcomes measurement to examining the ways in which students are engaged in "educationally purposeful activities," including activities that complement and contextualize their academic coursework.

In this paper, we present research findings that suggest differences in how undergraduate women and men perceive and practice engineering. We show that women and men differ in the ways they (1) define engineering as a field of study and practice, (2) approach engineering problems, and (3) participate in their overall higher education. These differences suggest a larger discussion about the extent to which undergraduate men and women are engaged in learning and doing engineering in context. In this paper, we explore the perceptions and experiences of students to address the following research questions: "To what extent are undergraduate engineering students learning and doing engineering in context?" and, "Are men and women learning and doing engineering in context to different degrees and in different ways?"

Methods

The Center for the Advancement of Engineering Education (CAEE) is a collaboration of scholars focused on the development of knowledge about engineering learning and teaching toward the improvement of engineering education. The Academic Pathways Study (APS) research element of CAEE is a multi-institution, mixed-method, longitudinal study which examines engineering students' learning and development as they move into, through, and beyond their undergraduate institutions. Data were collected from students at each of four institutions: Mountain Technical Institute (MT), a public university specializing in teaching engineering and technology; Oliver University, a private historically black mid-Atlantic institution; University of West State, a large public university in the Northwest U.S.; and University of Coleman, a medium-sized private university on the West Coast (pseudonyms).

The Academic Pathways Study uses a concurrent triangulation mixed-methods design, in which both qualitative and quantitative methods are employed to collect and analyze data. The integration of results occurs during the interpretation phase.[8] This allows researchers to answer a broad range of research questions directed toward discerning complex phenomena like student learning and development.[9] Data were collected from students at the four institutions using surveys, structured and unstructured interviews, and ethnographic observations. Students were also asked to perform simple engineering tasks during timed sessions at the conclusion of interviews. The study was designed to collect data from forty students at each of the four institutions (n=160). In each of the first three years of the study, surveys were to be administered to all student participants. In the first year, structured interviews and performance tasks were to be administered to thirty-two of those students at each of the four institutions (n=128), and unstructured interviews and ethnographic observations were to be conducted with the remaining eight students at each institution (n=32). Sample sizes have changed during the first three years of the study as some students transferred out of their schools, the major, and/or the project. Data analysis for each of the methods is ongoing.

In the interpretation phase, members of the research team representing each research method and institution came together for a two-day workshop to compare emerging findings. Researchers were encouraged to think beyond their own datasets, to see how others' findings complemented and/or contrasted their own. The authors had each observed modest gender differences while analyzing their respective datasets, and we met several times during the workshop to discuss our findings and explore emerging research directions.

Early in these conversations, we developed a comprehensive list of data analyses that had been conducted to date for each of the methods with which we had been involved. Next, we brainstormed themes supported by several of those analyses. "Engineering in Context" materialized as one of the most interesting and well-supported themes. Focusing on relevant data analyses, we continued to interpret our various findings and describe how they converged with one another around the larger theme. Table 1 shows the relevant data analyses discussed in this paper, and the research methods in which they originated.

Table 1: Data analyses and research methods

	Longitudinal Survey	**2nd year Structured Interviews**	**Longitudinal Unstructured Interviews**	**1st year Engineering Performance Task**
Level of (dis)engagement in liberal arts courses	√			
Nature of participation in extracurricular activities	√	√	√	
Social motivation to pursue engineering	√	√	√	
Ways of knowing engineering		√	√	
Ways of doing engineering				√

The survey consisted primarily of closed-ended Likert scale questions. Structured interviews contained pre-designed, highly structured, open-ended questions. Unstructured interviews were minimally structured, combining several pre-defined, open-ended questions along with extemporaneous follow-up questions and prompts. The engineering performance task was a ten-minute, written exercise during which students were asked to answer an open-ended question about a specific engineering problem. As necessary, we will describe each method in greater detail below.

Findings

Using the overarching "Engineering in context" theme to frame our examination of the findings of gender differences and commonalities emerging from each of the methods, we identified four related claims. First, several of us had observed some gendered differences in the way students define and delimit engineering, with women conceptualizing engineering more broadly than men. These modest differences in definition were accompanied by the comparatively wide approach women took toward the engineering performance task. Indeed, when we looked at levels of engagement with their overall higher educational experience, women tended to be more engaged in a wider spectrum of educationally productive experiences. However, in thinking about engineering as a profession situated in the larger social world, both men and women are equally motivated to pursue engineering for the greater good. These findings are discussed in greater depth below.

Women and men define and delimit engineering differently

The structured interview was designed to be administered annually to 32 students at each of the four APS institutions (n=128). As students switched to other majors, transferred to other academic institutions, or left the study, this number decreased. Among other things, we asked students to define engineering during their first, second, and third years in the study. Structured interview responses from second-year engineering students were used here to assess students' level of understanding of what engineering means. The sample in the second year consisted of ninety-one students: sixty-six male (72.5 percent) and twenty-five female (27.5 percent). For further information about how the structured interview data were collected and analyzed, please see Eris *et al.*[18]

Students were asked, "In your own words, would you please define engineering?" Students answered aloud as much or as little as they liked. Their answers were recorded and transcribed. Then, the data were categorized and coded, with multiple codes possible for any individual student. As shown in Table 2, the four categories of response with the greatest frequency levels include: problem solving (48.4 percent), math and science application (37.4 percent), designing/creating/building (37.4 percent), and improving humankind (28.6 percent).

Table 2: Second-Year Students Define Engineering

Highest Response Areas	**% Responses**	**Male**	**%**	**Female**	**%**
Problem Solving	48.4	29	44.0	15	60.0
Math and Science Application	37.4	28	42.4	6	24.0
Designing/Creating/ Building	37.4	22	33.3	12	48.0
Improving Humankind	28.6	21	31.8	5	20.0

In general, both men and women saw *problem solving* as a major component of engineering. However, a higher percentage of female respondents, 15 of 25 (60%) prioritized problem solving as a key component, while less than half of the men, 29 of 66 (44%) did so. The inclusion of *math and science application* also rated high amongst male students in the study; mentioned at twice the frequency as females in the study. Conversely, women defined engineering in terms of *designing/creating/building* at a higher rate than men. As Felder *et al.* have argued, all engineering students tend to be visual rather than aural learners, so these differences in definition do not necessarily reflect any actual gender differences in learning style.[10] Rather, they could be a reflection of gender differences in perception. Furthermore, it is quite interesting that a greater proportion of men than women included *improving humankind* in their definitions of engineering. Considering the weight of women's development literature that documents their socialization as caregivers and connected knowers, we wonder if women engineering students continue to set the study and practice of engineering apart from other activities that they would consider to be in service to their community and the world?

A close reading of student responses further indicates that women and men conceptualize engineering differently. Regardless of the respondent's sex, responses tended to be similar in length and complexity. However, men's answers tended to be more linear, direct, and technically based. One young man defined engineering as "coming up with a solution to a problem in an economical way." In contrast, women tended to define engineering more broadly. A female respondent defined engineering as "like the middle man between the inventor and the manufacturer, so [it's] the person that gets an idea and makes it possible." In identifying and emphasizing the relational nature of engineering activities, this respondent seems to recognize the non-technical aspects of who does engineering and who benefits. Not only did women more often define engineering beyond its traditional technical foundations in math, science, and efficiency, but they also drew from beyond traditional technical discourse to construct their definitions. As feminist psychologist Carol Gilligan[11] and critical theorist Hélène Cixous[12] among many others have argued, women think and speak in a "different" voice to describe their experiences and perspectives accurately.

In fact, on at least one campus in our study, these gender-based differences are evident in choices students make in how they spend their time. During her first-year unstructured ethnographic interview at MT, Michelle characterized the tangible difference between the women and men on that campus:

> "I'd have to say there isn't an *average* engineering [student]; they're very ah-, they're all unique, let's put it that way….I was really surprised when I came up here at the female population because I think that is really diverse, just as far as interests and what people are like. Just, I don't know; the guys kinda come out cookie-cutter….[The guys] want to do math, sit and play on their computers, and video games afterwards; but the girls have more, very diverse interests…

It is not only in the classroom or in campus activities that differences between female and male engineering students is observable. The way male and female engineering students know their worlds is inherent in how they live their daily lives. In the same way that their ways of knowing are observable in their daily lives, we would expect differences between the ways men and women conceptualize engineering to be realized in the way they actually do engineering,[13] and we encounter this phenomenon in our research with the engineering performance task.

Women and men frame engineering problems differently

In each year of the Academic Pathways Study, students were asked to address specific engineering problems devised first to elicit responses that reflect aspects of their engineering knowledge and skills, and second to reveal how they apply this learning to engineering-design practice. In their first and third years, students were given ten minutes to write their answers to the question, "Over the summer the Midwest experienced massive flooding of the Mississippi River. What factors would you take into account in designing a retaining wall system for the Mississippi?" The purpose of this performance task was to analyze the breadth to which students framed an engineering problem. This is important, because defining the problem is as important as solving it[14] and framing is among the most difficult aspects of engineering design to assess and teach.[3]

During the first year of the study, the task was administered to forty-three women and eighty-one men (n=124) at the conclusion of either the structured or unstructured interviews described above. Four students out of the original 128 did not participate in the engineering performance task. Students' written responses were transcribed and segmented into distinct ideas (segments), which were then coded on two dimensions of problem scoping breadth: physical location and frame of reference.[14, 15] Location codes record the physical focus of each idea: on the wall itself, the water, the riverbank, or wider surroundings beyond. Frame of reference codes record the perspective represented in each idea: technical, logistical, natural, or social considerations.[16]

Segments were then interpreted to be focused on design detail or design context, based on their codes. As illustrated in Figure 1, ideas focused on the wall or the water and, from a technical or logistical perspective, were interpreted to be oriented toward the detail of the design problem. All other ideas were considered oriented toward the context of the design problem.

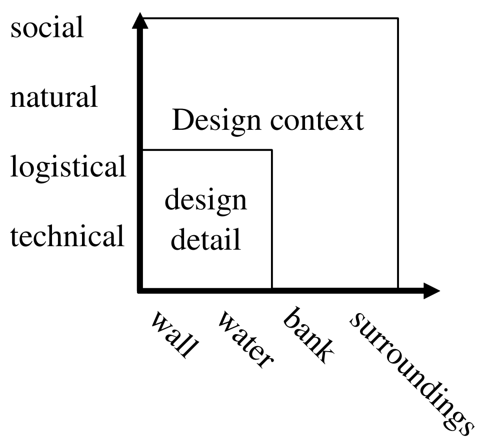

Figure 1: Interpretation of Midwest Floods Problem codes

For example, a stated factor such as, "materials for the wall" was assigned the codes "Wall" and "Technical," and therefore interpreted as oriented toward the design detail. This stands in contrast to "people who live in the flood plain," which was assigned the codes "Surroundings" and "Social," and was identified as oriented toward the design context. Table 3 contains findings from the Midwest Floods performance task, as administered in the first year of the Academic Pathways Study.

Table 3: Findings from Midwest Floods Problem, Year 1, by gender.

	All	Women	Men
Count	124	43	81
Average number of segments	11.48	13.09	10.62
% Design detail	53%	44%	53%
% Design context	47%	56%	47%
Average number of design detail nodes	5.51	5.63	5.44
Average number of design context nodes	5.93	7.40	5.15

On average, women's answers contained more segments—or distinct ideas—than men's. While men (n=81) averaged 10.6 distinct ideas in response to the Midwest Floods problem, women (n=43) averaged more than thirteen. A Mann-Whitney test on the two samples revealed a significant difference in number of segments (p=.017).

Women's additional segments were comprised almost entirely of factors pertaining to the design context. While women and men had roughly the same number of ideas oriented to the detail of the design problem, women gave greater attention than men to the context of design. The Mann-Whitney test of the two samples revealed a significant difference in the average number of segments oriented to the design context (p=.008). When the Mann-Whitney test shows significant difference, it means we do not expect the difference between the two samples to have arisen by chance.

These findings from the students' first year of study suggest that women were more aware of how an engineering task is situated within and interacts with its context. As learning theorists and engineering education scholars have argued, the power of engineering technical knowledge is only realized when it can be applied in a specific context.[2-3,13] Our data indicate that, early in their programs, women demonstrated a greater sensitivity to context than men. Likewise, we shall see that women are more broadly engaged than men in their overall engineering education, which also has positive implications for learning and satisfaction with and commitment to engineering.

Women and men are differentially engaged in engineering education

Every student participant in the structured interview in the second year of the study responded affirmatively to the question, "Have you had experiences that enabled you to develop engineering knowledge?" In describing those experiences, students provided a broad range of responses, as illustrated in Table 4. Two-thirds (65.9%) of the students indicated that they gained engineering knowledge from their engineering classes**.** Experiences mentioned less frequently but still coded in the highest response category included: extracurricular activities, hands-on experiences, and internships and research.

Table 4. Experiences That Develop Engineering Knowledge

Highest Response Areas	**Frequency**	**Percent**
Engineering Classes	60	65.9
Extracurricular Activities	19	20.9
Hands-on Experiences	17	18.7
Internship/Research	16	17.6

As research spanning several decades has shown and as confirmed with the most recently completed National Survey of Student Engagement, "college students learn more when they direct their efforts to a variety of educationally purposeful activities"[17] such as these cited by students in the structured interviews.

From our survey data, we have observed some interesting differences in the way men and women engage with their engineering education. The Persistence in Engineering (PIE) Survey instrument was designed to investigate correlates of persistence. Full details of the survey design and of the specific constructs, as well as preliminary results and analyses, can be found elsewhere.[17, 18] The PIE has been administered twice annually to all participants at each of the four APS campuses, beginning during Fall 2003, the participants' first year in college. Six surveys have been administered since then. The seventh and final administration, which will be during the students' senior year, is scheduled for Spring 2007.

The raw data from the surveys was then processed for analysis. As different survey items had different response scales, the score for each construct was normalized by a linear mapping to a scale of 0 and 1. Data for all timepoints were pooled and t-tests were used to determine differences between men's and women's responses (reported as an 'overall' p-value). T-tests were also performed to determine differences at individual timepoints. A t-test determines whether the means of two groups of responses are sufficiently different that we can assume the difference is not caused by chance. The t-test is computed differently depending on whether the two groups of responses have equal variances or not; that is, how widely individual responses are dispersed around the mean response is approximately the same. Levene's test was used to assess equality of variances and ensure that the appropriate t-test was used. Statistical significance was set as $p<0.05$.[18,19]

To measure students' levels of disengagement with various courses, we asked them to tell us how often they came to class late, skipped class, turned in assignments that did not reflect their best work, turned in assignments late, or thought classes were boring. Women reported less disengagement in both their engineering courses ($p = 0.03$) and, as illustrated in **Figure 2**, liberal arts courses ($p < 0.0005$) when compared to their male peers. Also, women reported less disengagement overall ($p < 0.0005$).

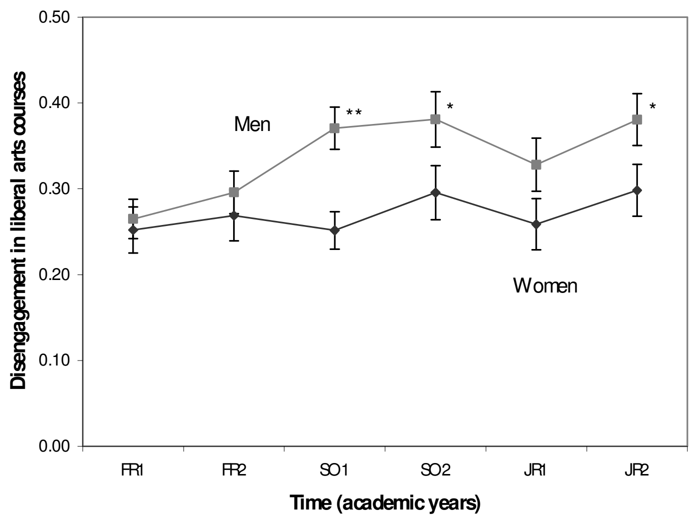

Figure 2: Disengagement in Liberal Arts Courses. The value for the construct is a normalized score on a scale of 0 to 1. Data are presented as mean ± SEM. ** p<0.005 for men and women at this timepoint. * p = 0.06 at this timepoint. Note that this scale measures disengagement; lower scores indicate more engagement with liberal arts courses.

One of the recommendations in *Educating the Engineer of 2020*[20] is a focus on creating self-directed learners. Self-directed learners are capable of identifying their own learning goals and organizing the means to meet those goals.[21] Engineering graduates are expected to be able to continue learning beyond the engineering classroom. This sentiment is echoed by ABET Engineering Accreditation Criterion 3(i)[5], which requires engineering students to demonstrate an understanding of the need for and an ability to engage in lifelong learning. Our finding that women are less disengaged overall than men suggests that women currently are taking greater responsibility for their own learning, a necessary prerequisite of lifelong learning.

Similarly, ABET has identified a "knowledge of contemporary issues" and a "broad education necessary to understand the impact of engineering solutions within a global and societal context" as important characteristics of graduate engineers.[5] While it is difficult to directly map liberal arts education to these parameters, an interest in the liberal arts is representative of interest and concern with society outside the strictly technical, as well as being demonstrative of an interest in different perspectives. As Drew, a male civil engineering major from the Caribbean attending Oliver University, described:

> This semester I'm doing Women in Literature; God knows why I chose that. I was trying to enlighten myself, because I'm in the sciences, so it's, I don't just want to do stuff that is in my major. I need to do something outside [that] someone in my major is not normally gonna do.

In the aggregate, though, men tend to be more disengaged than women, not only with regard to their liberal arts courses, but across academic activities. This may reflect a broader disengagement with context more generally speaking.

In addition to their relatively lower academic disengagement, female students report higher levels of extracurricular fulfillment than their male colleagues ($p = 0.002$), suggesting that they are more fully engaged with their academic environment. This is further substantiated by the higher degree of satisfaction with the overall collegiate experience reported by female students ($p < 0.05$); this is consistent with previous findings that higher levels of engagement and extracurricular fulfillment are positively correlated with higher retention rates and increased degrees of satisfaction with the academic experience.[22]

Ethnographic research deepens our understanding of student engagement with an in-depth exploration of undergraduate engineering students' experiences through unstructured interviews and ethnographic observations. At Oliver University, the difference between engineering-oriented and non-engineering-oriented extracurricular activities is clarified in the voices of four first-year students.

Drew, a male Civil Engineering major, sought extra-curricular activities outside the School of Engineering, although he did prioritize participating in National Society of Black Engineers (NSBE). He explained, "I just feel association with [NSBE] would benefit me more than it could possibly harm me, and that's just how I feel." When asked about the benefits of NSBE, he replied, "Number one: their scholarships...number two: it gives me opportunity to be involved in extracurricular activities that can build skills that I need, like leadership, teamwork, and that kind of stuff. And it's just a healthy thing to be involved with."

Deborah, a female Electrical Engineering major, had trouble in her first year balancing between her activities outside engineering and her engineering studies. During her interview, she described intending to focus more on engineering-oriented extracurriculars in the future—including NSBE. "This semester I didn't do much in engineering itself, mostly like, like clubs, the extracurricular things outside, just generally nothing very specific to engineering….They have career fairs and stuff like that, but I really didn't do much in engineering, so I'm trying to do that more next semester."

Mark, a male Civil Engineering student, found his first year extremely difficult, because, "I play football out here, too. I joined in September and like it wasn't a scholarship, I just walked on." Mark said his academic advisor was incredulous. "He asked me, 'Are you sure you want to do civil engineering and football?'" Mark described the overwhelming workload: "The classes are ridiculous; the work is ridiculous, but at the same time, football takes up a lot of time."

Paula, a female chemical engineering student, focused on her experience with NSBE in her interview. "There's no bad experience. NSBE's good, the networking, the environment, the people, the information more so is really good because going to NSBE I talk to so many chemical engineers and they tell me, like, what to do, little tips, like how to prepare for next year, and how to stay or get better or more focused for this year."

All of these Oliver University students were active in extracurricular activities, but they said that non-engineering-oriented activities competed with their academic coursework for their time and energy, while engineering-oriented engagement in NSBE was perceived to be a positive experience. It may be interesting in future research to distinguish between non-engineering-engineering-oriented extracurricular activities. The former may indicate voluntary engagement in the larger social context and reflect the "truer" range of one's interests, while the latter may reflect more pragmatic decision-making in an effort to increase one's chances of success in engineering study and practice.

In contrast, engagement at Mountain Technical Institute (MT), whether it is engineering-focused or not, appears associated with positive student outcomes and potentially with the practice of engineering. Consider Max and Hilary, two participants MT students with similar backgrounds, majors, and expected career paths. Both have parents and adult mentors with expertise in engineering, and both look forward to careers as engineers in the oil and gas industry although in different majors: one student is pursuing expertise relevant to extraction; the other, to refining. One expresses deep satisfaction with the experience of studying engineering at MT; the other, general satisfaction. The principal difference between them which could explain their perceptions is in their level of engagement.

Max was raised in a small town about forty-five minutes from MT; both his parents have engineering expertise. His mother is an electrical engineer with a career in computing; his father, a geologist with lengthy expertise in the oil and gas industry. From early in his life, Max was interested in engineering and describes particular interest in the earning potential offered by engineering careers in the oil and gas sector. He selected MT because of its reputation as a good school, recommendations from his father's oil and gas colleagues, and because the school neither offers nor expects extensive coursework outside the technical requirements of engineering degrees. Max identifies students at MT as "being here to work" rather than socialize, develop adult identities, or attend parties. Max maintains strong friendships with friends from high school and frequently travels to his hometown to visit those friends, one of whom is female studying in a healthcare field at a university about one-hour's drive from MT and whom Max marries between his junior and senior years at MT.

One of the few activities Max pursues while on campus and with peers from campus is routine drinking on Thursdays after classes are finished. Max is extremely concerned about not driving drunk, and, although his Thursday drinking episodes are extensive, he always stays in his apartment or in the apartment/home of a friend. On campus, Max's friends are all from his home department; because of the scheduling demands for MT's students, commonly after the first year students have little academic contact with anyone outside their majors. Max also identifies what he calls the "geeky" aspects of many students at MT; he describes his peers' introversion and lack of interest in other people and the world at large. During interviews and informal conversations, Max expresses interest in the progress of the APS study, asks about findings, and about the researchers.

During holiday breaks and summer vacations, Max has sought and received industry internships; strategically, each has been in a different sector to provide broadened perspective on the industry. In his junior and senior years at MT, he has worked at least one day a week in a job that grew out of these internships. Other than his Thursdays at home, Max's campus-related activities have been to join the MT student chapters of two professional societies. He describes with awe and pleasure the meetings of one of them, which includes lavish food, beverages, and opportunities to mingle with seasoned industry professionals. Max's goal is to graduate from MT with a GPA above 3.0 so as to be attractive to recruiters. Although Max reports being excited about going to work as an engineer, he describes "hating" MT. He believes his program has prepared him well to enter the oil and gas sector as an engineer but reports despising the process that he experienced to become an engineer.

Hilary's engineer father taught undergraduate Physics when she was a child, and she describes growing up in the lab with first-year students struggling to come to grips with the science. Her mother is a teacher, and the family places a high value on knowledge and competence. Hilary's mother predicted her interest in engineering when Hilary was a child because of her interest in how things work. After her father left academia, her family then moved to an oil-producing state where her father is employed in the oil and gas industry. She had extensive contact with engineers in the field, and their recommendations of MT were a principal factor in her decision to matriculate there; the institution has a strong recruiting and placement record in that state.

As an undergraduate, she quickly chose an engineering major that plays a principal role in the oil and gas field because she knew it would be instrumental in seeking work in the state where her family lives. She also chose this program because it would provide flexibility if the oil and gas sector were to collapse. Hilary has been heavily engaged with the MT campus as a varsity athlete, on the student leadership council for student athletes, and as the captain of her team in her senior year. During the long bus trips—up to eighteen hours each way—en route to competitions, Hilary describes how the women athletes do homework and strategize how to make their way through MT; older students provide advice and homework coaching to younger students. In her earlier years, she relied heavily on the guidance of more senior student athletes to shape her academic success and has missed having more senior people to give her advice during her senior year. She also enrolled in an interdisciplinary minor program which develops a strong cohort among students within a class (first-year, sophomore, junior, senior). When her varsity sport is out of season, Hilary laughs that her roommates insist that she go to work out to burn off some of her abundant energy; in off-season, she plays on intramural teams. Hilary believes the discipline of competitive sports has been instrumental in her success as an undergraduate engineering student; her GPA at the end of her junior year was 3.97.

Each year, Hilary has sought and received pre-professional internships in her home state; her first was with the Army Corps of Engineers; her second and third, with a large, multinational oil corporation, which has offered her a post-graduate position. She has been deliberate about choosing internships that would give her broad insight into the workings of her future profession as an engineer. Hilary joined the pre-professional society associated with her major but has not described it as an active influence on her emergence into her engineering profession. The organization has given her contact with upper-class students in her major to help with navigating the major. Hilary reports enjoying her experience at MT, feeling satisfied with her education, and understanding that engineering school is difficult and sometimes not much fun.

Hilary exemplifies a high level of engagement, general satisfaction with her studies and MT, and enthusiasm for engineering as a profession. Max demonstrates a low level of engagement, great dissatisfaction with his studies and MT, yet enthusiasm for engineering as a profession. Both pursue relevant internships during holiday and summer breaks and have some level of engagement with pre-professional societies. Both believe their experiences at MT are preparing them to practice engineering upon completion of their degrees and both will complete their degrees in four years. Hilary and Max bracket the range of female/male engagement among engineering students at MT. The stark contrast between their engagement and satisfaction demonstrating differences between females and males is at the extreme, but neither participant is unique in her or his approach to managing undergraduate studies and personal pursuits beyond the classroom. On the survey in both the sophomore and junior years, women reported higher degrees of extracurricular fulfillment than men ($p<0.005$).

Given his exposure to engineering prior to enrolling at MT, we would expect Max to be as committed to his education and future profession as Hilary is. Other APS data suggest that having family members who are engineers and other prior experiences with engineering are associated with higher levels of commitment to and satisfaction with engineering. As demonstrated here, even though they have had similar levels of exposure to engineering, Hilary is significantly more satisfied with her undergraduate engineering experience than is Max; the principal difference between the two is their levels of engagement with the institution.

This finding has several implications for engineering education. Students with similarly low engagement levels as Max's but with significantly lower prior exposure might be students who are at risk of being lost to engineering; such students might leave the major before completing the degree. However, a lack of engagement might also have implications for professional engineers. Pascarella and Terenzini found that students who are engaged in their college studies through extracurricular activities demonstrate greater levels of leadership and higher confidence in and greater mastery of professional skills, including leadership and teamwork[23]. A student who has progressed satisfactorily through engineering studies but has been disengaged throughout that experience may be a less desirable employee who might not be as prepared to undertake the various and broad skills required of the workplace. Finally, as revealed in data from MT, engagement may be an indicator of long-term commitment to the engineering profession.

Even though he regularly expressed dissatisfaction with his educational experience, Max seemed engaged professionally, as evidenced by his regular internships and part-time work during his junior and senior years at MT. Furthermore, Max had always emphasized his interest in engineering as a means to a high salary, and his wife was also pursuing a well-paid professional career. He anticipated that he and his wife might each work long hours to establish themselves in their new careers and described the young couple's need to make lots of money because of their plans to buy a house and settle into adult living. However, when the interviewer asked how family life—with children—would feature into a dual-career couple, Max easily responded that he might leave engineering to stay at home with his future kids. Despite his satisfaction with his future career in engineering, Max did not hesitate to suggest that he might leave the field behind. If his lack of engagement with MT led to disengagement with the profession of engineering, Max's surprising potential career switch speaks to the tenuous commitment to practice of an unengaged engineering student. It is possible that engagement is essential not only to seeing that engineering students graduate but that engineering graduates continue to practice in the field.

Our data show that students acknowledge that their engineering knowledge comes from educationally productive activities, but they are differentially engaged in those activities. Women are less disengaged in their classes than men. In addition, while engagement in extracurricular activities presents complex effects depending on whether the activities are engineering related or not, engagement in these productive activities also shows positive outcomes for students, and women show higher levels of engagement here, as well. A large body of both theoretical and empirical studies support the idea that student learning and development in the collegiate years is strongly related to the level of engagement brought to their studies [eg Astin 1993, Pascarella and Terenzini 2005, Chickering and Reisser 1993, Hutto 2002 (review)]. Consistent with their lower levels of disengagement in both engineering and liberal arts courses, as well as higher levels of satisfaction with extracurricular activities, female students appear to be closer to the ABET target of broadly-educated, contextually-aware, self-directed learners.

Discussion and Implications

The implications of this research are significant, given the ever increasing need in the U.S. for more highly skilled engineers. Analysis of this data revealed that women define engineering, approach engineering problems, and engage in their overall engineering education more broadly than men. Interestingly, the women considered contextual factors in addition to (rather than instead of) factors oriented toward the details of the artifact being designed (the retaining wall, in the example from the first year of this study). In this sense, their approaches to the engineering task were broader than the men's. Given that this difference was observed in the first year, early emphasis of such practices is critical.

Prior educational research has also suggested that underrepresented minority populations are more successful in higher education environments that place high emphasis on context. These findings are highly suggestive for how engineering education might do better recruiting into engineering women and underrepresented minorities. However, given examples in the ethnographic data that illustrate how male participants are dissatisfied with their experiences in engineering school, as well as the data that demonstrate that males are less engaged than females, these findings could also be useful in addressing concerns of persistence among the traditional engineering population, white men. With greater mechanisms for engagement, engineering colleges might find all their students to be more satisfied with their undergraduate experiences. If our findings were used to restructure engineering programs, a more holistic approach might help to graduate students who are better prepared as practitioners to meet the national need for engineering talent.

We see this analysis as further evidence for the engineering education community that women are as prepared to study engineering as men. Indeed, they may be *more* prepared, considering their greater attention to context. Given our vision of the Engineer of 2020 as an engaged, creative, contextually aware practitioner, engineering education should be more responsive to women's interests and qualities and should do a better job to provide opportunities for all students to develop similarly.By shifting curricula from traditional practices into reliance on engaged pedagogy and campus communities, we not only will improve our ability to attract and retain diverse students , we will also produce the kinds of engineers we envision to meet the needs of a global society.

Finally, our rich, multi-method view of context and engagement offers interesting new directions for further research to better understand how engineering education can adapt itself to meet national needs for more and better engineers. With this window into the existence of differences between how women and men address engineering problems, new targeted research could emerge to better understand how differences in other populations might be addressed pedagogically to better serve those students. Research that could provide answers to some particularly troubling questions regarding engineering's declining and relatively un-diversified enrollment would be a major contribution to the field and to the nation.

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