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An Investigation into How One Engineering School is Approaching Gender Diversity

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An Investigation into How One Engineering School is Approaching Gender Diversity

Abstract
Nationally, the percentage of women earning degrees in engineering remains low despite continued efforts to attract and retain women. In 2016, however, more than 50% of the undergraduate degrees in engineering awarded at the Thayer School of Engineering at Dartmouth (Thayer) went to women, and well over 40% of the current engineering students are women, a level more than twice the national average. What is our campus doing differently to successfully attract and retain women in engineering?

Several things set the engineering school at Dartmouth apart from other campuses. Key differences include the fact that the engineering school is part of a liberal arts campus, is fairly small, and has no separate departments within engineering. As with many liberal arts universities, students are admitted to the campus but do not declare a major until they are sophomores, giving them time to explore different courses and departments before declaring a major. Dartmouth is a private institution. Students are admitted to Dartmouth by the Admissions Office; the engineering school does not participate in the admissions process nor do they influence selections.

In order to better understand why our campus has been successful at attracting and retaining women in engineering, we examined our program and enrollment trends, conducted interviews, and surveyed faculty, students and alumni. Based on this data, key aspects of the curriculum that seem to effectively attract and retain women include the flexibility of the curriculum, a focus on design and innovation, a collaborative and friendly atmosphere, the presence of female peer mentors, an emphasis on the liberal arts, and a focus on real-world projects.

Data from surveys, interviews and courses are shared so that faculty and administrators at other campuses may learn about different strategies that could be adapted at their own campuses to increase gender diversity.

Background
Despite continued efforts to attract and retain women, the percentage of women earning degrees in engineering remains low nationally. Women earned close to 60% of all bachelor's degrees in 2012 but less than 20% of those degrees were in engineering [1]. At Dartmouth, however, the percentage of women in engineering is approaching gender parity [2]. As shown in Figure 1, the percentage of female students graduating with a Bachelor of Arts in engineering at Dartmouth peaked at 54% in 2016. While the percentage of women graduating in engineering in 2017 went down, it remained high at 45%, which is more than twice the national average; the national average of women earning bachelor degrees in engineering is less than 20% [1]. Enrollment trends in current classes indicate that between 45 and 55% of the graduates will be women in upcoming years as well. What is our campus, and other campuses who are approaching gender parity, doing differently and how can these approaches be adapted at other engineering schools?

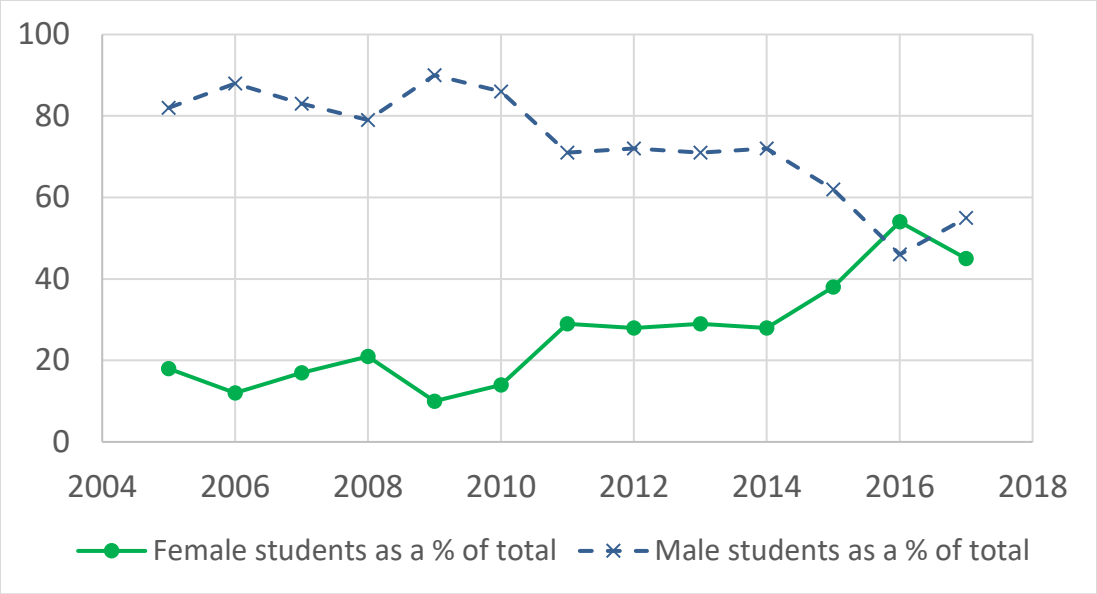

Figure 1. Students Graduating with a Bachelor of Arts in Engineering by Gender and Year

Engineering at Thayer School of Engineering at Dartmouth

Several things set the engineering school at Dartmouth apart from other campuses. Key differences include the fact that the engineering school is part of a liberal arts university, is fairly small, and has no separate departments within engineering. As with many liberal arts universities, students are admitted to the campus but do not declare a major until they are sophomores, giving them time to explore different courses and departments before declaring a major. Approximately 100 students graduate each year with a Bachelor of Arts (BA) in engineering. Due to the high percentage of liberal arts courses that students must take, the BA is not accredited in engineering. In order to gain more depth in engineering, students may opt to take an additional 9 courses to earn a Bachelor of Engineering (BE), which is an ABET-accredited degree. In 2017, 45% of those graduating with a BE were women. Approximately 75% of the BA students in engineering also complete the BE degree each year, with many completing both the AB and BE is less than 5 years. The average time to complete the BE at Dartmouth is 4.7 years with ~30% of students completing both the AB and BE in 4 years and over 90% completing both degrees in 5 years. Nationally only 53% of students who enrolled in 2009 in four-year, private institutions completed a degree in 4 years and 66% completed a degree in 6 years [3]. Most European institutions require 5 years of study for an engineering degree.

While the number of faculty in engineering at Dartmouth has grown over the years, the number of full-time teaching faculty remains fairly small. The faculty in the Thayer School of Engineering at Dartmouth includes 38 tenure-track faculty members, 5 instructional faculty members, and 11 research faculty members. Faculty members on the instructional track are expected to teach more than tenure-track faculty members but are not expected to conduct research and are not eligible for tenure. Faculty members on the research track are expected to develop a strong research program, develop their own funding sources, and are not eligible for tenure; research faculty typically have no teaching responsibilities. Like many engineering schools, the percentage of female faculty members is quite low. Overall 19% of the faculty are female, with a higher percentage of females among instructional and research faculty (non-

tenured positions) than among tenure-track faculty. The percentage of females among tenure-track, instructional, and research faculty are 12%, 40%, and 27%, respectively. Note that the percentage of female engineering faculty at Dartmouth is less than the national average; nationally 25% of all postsecondary faculty members are women [1] and 16% of tenured or tenure-track faculty members are women [4].

Course Enrollment Trends

In order to explain the high percentage of women in engineering at Dartmouth, we looked at many things including the courses that women were taking. Women tend to gravitate toward certain types of courses. Data collected by the American Society for Engineering Education shows that women tend to be well-represented in biomedical, environmental, biological and agricultural, architectural and industrial engineering [4], with women earning over 30% of the bachelor's degrees in these disciplines. The trends at Dartmouth are similar, with women tending to gravitate toward biomedical and environmental engineering courses and concentrations.

Courses numbered 1 to 19 at Dartmouth are meant for freshmen trying to better understand engineering and still deciding on a major as well as for non-majors fulfilling distributive requirements. As shown in Figure 2, women tend to gravitate toward the design, health, and biomedical-related courses. The course with the highest percentage of women is Engineering Sciences 12 (ENGS12), *Design Thinking*, with over 70% women. This course is a very popular course among non-majors and majors alike and is offered every term. In the *Design Thinking* course students focus on campus problems, designing solutions in teams. The data shown in Figure 2 represents a single academic year but the trends in enrollment for the previous 5 years are very similar. Other courses that are popular among women include *Virtual Medicine*, *Global Health* and *Systems and Policy Design*. The *Technology of Cyberspace* and *Digital Imaging* courses are also popular among women based on Figure 2 but it should be noted that enrollment in these courses was fairly small (<10 students in each course) so the results may be somewhat skewed. For comparison, enrollments in the other courses listed ranged from 40 to 100.

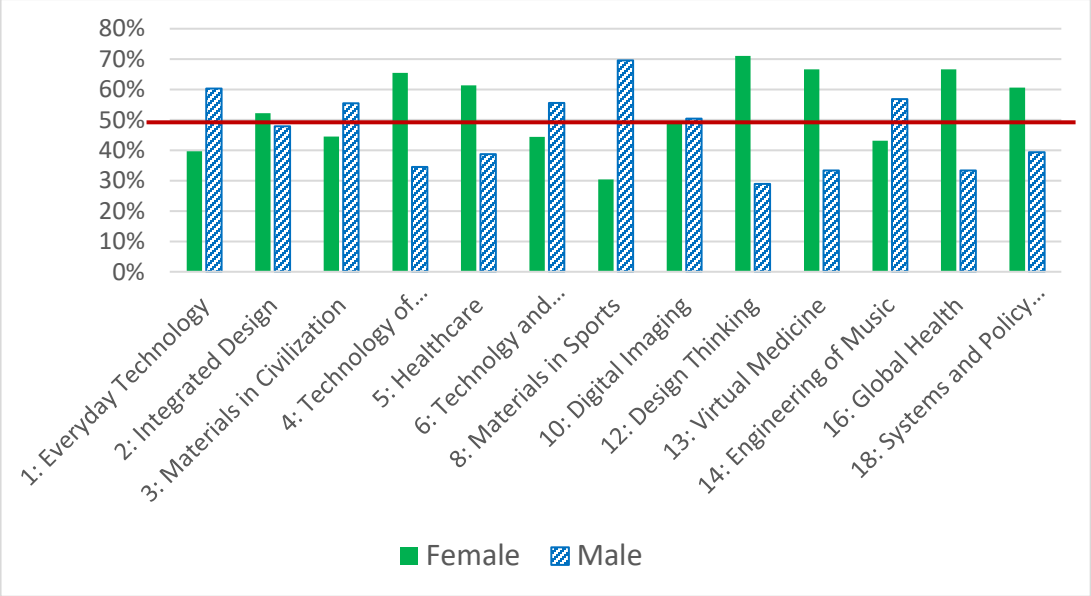

Figure 2. Student Enrollment in Non-Major Courses by Gender in 2015-2016

Engineering students at Dartmouth must take two gateway courses, from different disciplinary areas. These gateway courses are numbered in the 30s and cover a range of topics. As shown in Figure 3, *Biochemical Engineering* had the highest percentage of women. Other courses that were popular with women included *Biological Physics*, *Fluid Mechanics*, and *Chemical Engineering*. These courses are pre-requisites to many of the biomedical and environmental engineering courses, which like national trends tend to attract more women [4]. It is somewhat surprising that the percentage of women in Engineering Sciences 37, *Environmental Engineering*, is not higher but this course has a bit of a reputation and being very theoretical, is mainly lecture-based and enrolls fewer students overall than the other courses shown in Figure 3.

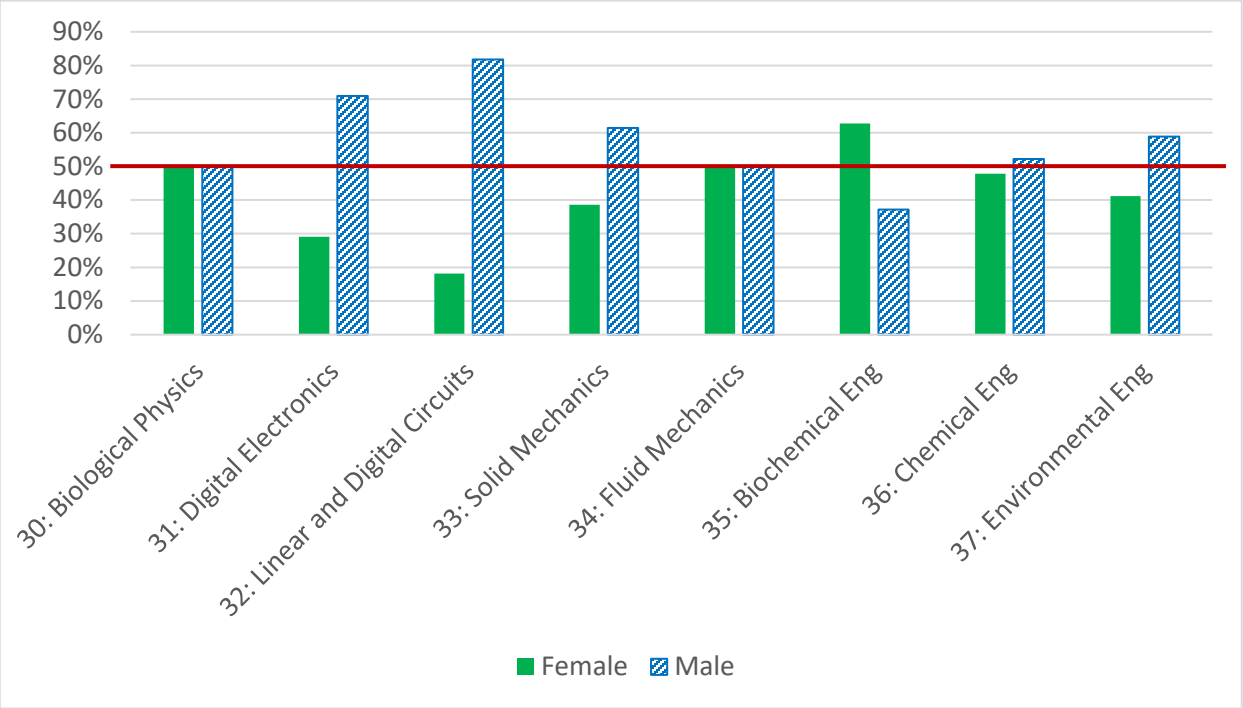

Figure 3. Student Enrollment in Gateway Courses by Gender in 2015-2016

Teaching Assistants

The engineering school at Dartmouth has been trying to hire women in all areas from support staff to teaching assistants to faculty members. One area where we've had success is in hiring teaching assistants for undergraduate courses. As a school, we decided to reach out to and hire women to serve as teaching assistants. Teaching assistants at Dartmouth are typically undergraduate students themselves who have done well in the courses for which they serve as teaching assistants. Responsibilities of the teaching assistants include running problem sessions (optional evening help sessions), grading problem sets, and helping to set up and run demonstrations and laboratories. Teaching assistants are not responsible for grading quizzes, exams or projects. As shown in Figure 4, the percentage of women serving as teaching assistants in undergraduate engineering courses for the past six terms has been quite high, ranging from 47% to 55%.

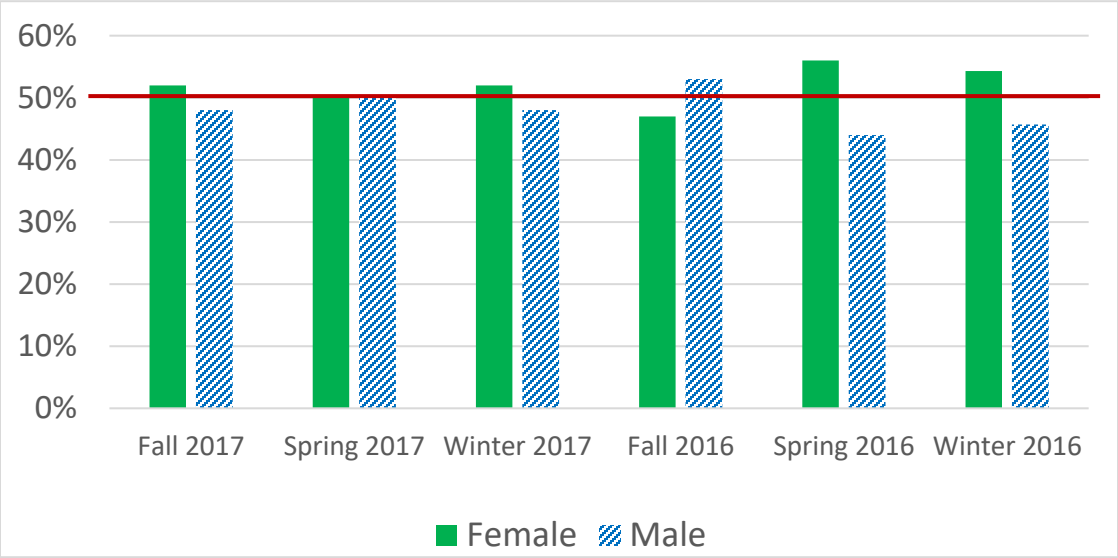

Figure 4. Teaching Assistants by Term and Gender (Overall)

In particular, the school as a whole has worked hard to employ female teaching assistants in Engineering Sciences 21 (ENGS21), *Introduction to Engineering*, since it is the first engineering course taken by most undergraduates. As shown in Figure 5, these efforts have paid off with over 50% of the teaching assistants being women in all but one of the past six terms and a couple of terms with over 70% of the teaching assistants in the course being female. *Introduction to Engineering* is taught during fall, winter, and spring terms. Class size tends to be fairly high with 60-70 students each term. The number of teaching assistants hired to help with the course is typically 10-14 per term.

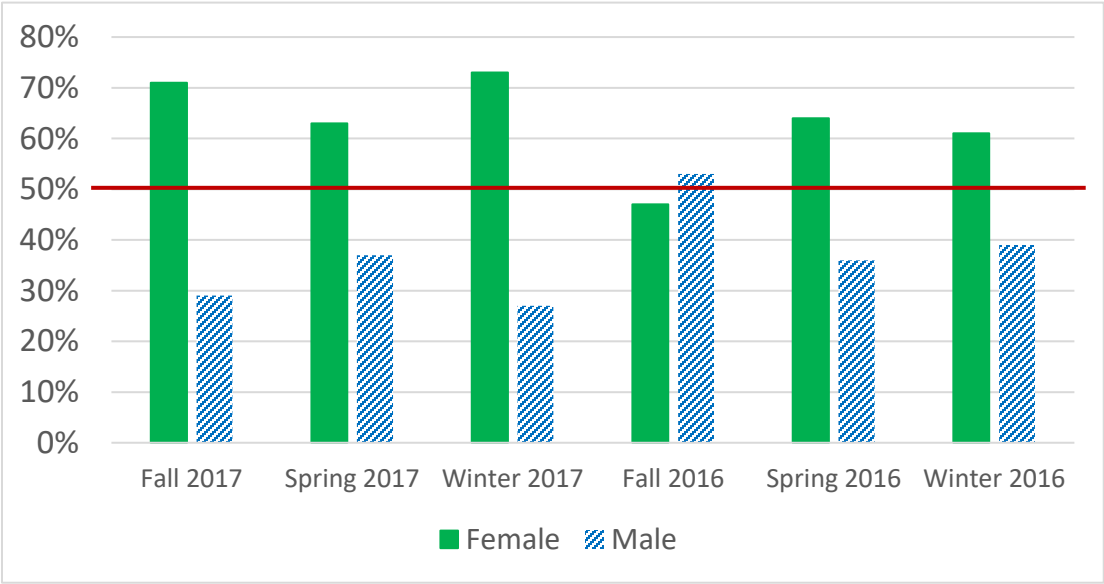

Figure 5. Teaching Assistants by Term and Gender (ENGS21 - *Introduction to Engineering*)

Survey and Interview Data

In another attempt to better understand why the percentage of women in engineering is high at Dartmouth, we surveyed faculty, students, and alumni. The surveys that we used are included in Appendix A and B. The goal of the surveys was to determine what factors faculty, students and alumni think are most important in helping Dartmouth to diversify. The survey was based on one developed by the Assessing Women in Engineering Program (https://www.engr.psu.edu/awe/). The number of respondents to the survey are shown in Table 1. The survey was administered as both a paper survey and as a web-based survey. All of the alumni responses were collected online and a mix of paper and online surveys were used for students and faculty. Most of the faculty surveys were collected on paper during a faculty meeting with a few collected through a follow-up online survey. Similarly, most of the surveys for students were collected on paper in three courses, with additional surveys collected online as a follow-up for those who missed class. The survey to alumni was emailed to 908 recent alumni.

Table 1. Survey Responses

	Faculty	Alumni	Students
Total Responses	29	95	60
Response Rate*	54%	10%	24%
Female Responses	7	51	30
Male Responses	22	44	30

*Response Rate = Total Responses Received / Surveys Sent or Given

The first question on the survey asked faculty, students and alumni to list three words to describe the Thayer School of Engineering to get a better understanding of how the engineering school is perceived and characterized. Figure 6 depicts graphically the words that were listed by students, alumni, and faculty. The size of the word in the wordle (https://worditout.com/word-cloud/) is proportional to the frequency with which it appeared in the responses.

Figure 6. Words Listed by Students and Alumni (left) and Faculty (right) to describe the Thayer School of Engineering at Dartmouth

In addition to the wordle, the words that were listed by alumni, students, and faculty were categorized and tabulated. Words that were similar were combined into a single category; for example, *creative* and *innovative* were included in a single category. The frequency of each word or group of words could then be determined. Table 2 lists the top eight words used by alumni to describe engineering at Dartmouth. *Collaborative* was the word used most frequently by alumni. While *collaborative* was not the *most* frequent word used by students or faculty it was one of the most frequently used words for those groups as well. The most frequent word used by students was *challenging/rigorous* and by faculty was *interdisciplinary*. It was a little surprising that alumni and students didn't use the word *interdisciplinary* more often to describe the program but in hindsight it makes some sense. Faculty generally came from traditional engineering programs so are aware of the fact that the engineering program at Dartmouth is more interdisciplinary. Alumni and students, on the other hand, don't typically have experience with other, more traditional departmennts so don't realize that *interdisciplinary* is a unique characteristic.

Table 2. Words Listed by Students, Alumni, and Faculty to Describe Engineering at Dartmouth

Word	**Alumni** frequency	**Student** frequency	**Faculty** frequency
collaborative	**16.3%**	10.7%	14.1%
creative/innovative	9.1%	6.7%	10.9%
hands-on	9.1%	9.4%	4.7%
project-based	6.4%	4.0%	14.1%
challenging/rigorous	6.1%	**15.4%**	1.6%
fun	3.4%	6.0%	0%
design-focused	3.0%	1.3%	6.3%
interdisciplinary	3.0%	1.3%	**18.8%**

Alumni and student surveys included a question asking them to list any faculty or staff members who had a positive impact on them. 95% of respondents listed at least one faculty or staff member, with many listing as many as five names. Of the names listed, 16% of those listed were staff members and 84% were faculty members, with 10% of the names being male staff member, 6% being female staff members, 24% female faculty members and 60% male faculty members. These percentages are not too surprising given that 81% of the faculty members at Thayer are male. What is a little surprising is that a relatively few names were listed. Two female faculty names, both instructional faculty, accounted for over 20% of the names reported and five male faculty names accounted for almost 40% of the names reported.

Surveys to alumni and students also asked them to rate the influence of different aspects of the program on a Likert scale from 1 (no influence) to 4 (significant influence). Figure 7 shows the aspects of the program that female students rated as a 3 (moderate influence) or higher. The

results for the alumni were very similar. Eleven of the twenty aspects that were listed were rated above a 3 by female students, with *atmosphere* being rated the highest and *caring faculty and staff* a close second. Other aspects that were rated highly included the fact that design and *creativity* were encouraged, the program was *project-based*, and there were opportunities to *collaborate* with peers. Similar categories and rankings emerged in interviews with students.

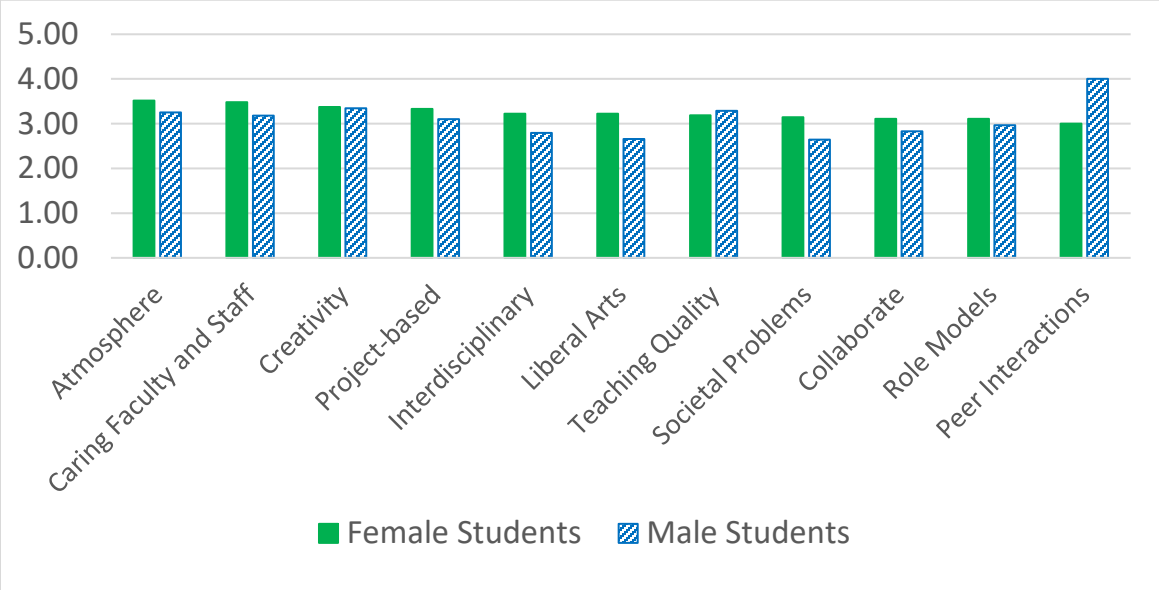

Figure 7. Factors that Influenced Students' Decision to Study Engineering (>3 out of 4 for female students)

On the survey and during interviews (all students are interviewed prior to graduating), students and alumni were also asked to provide open-ended comments. A sampling of comments from female students and alumni are listed below (bold type added by the authors of this paper). Most, but not all, of the comments were positive. Advising, in particular, emerged as not being effective at Thayer.

- "I kept meeting really **cool upperclassmen** who were engineers."
- **"ENGS 21** was a huge reason why I chose to major in engineering! I had had no other experience with engineering beforehand."
- "The **flexible liberal arts** degree was the #1 reason I became an engineering major."
- "As an undergrad, I majored in both Engineering and Math. In many ways, my experience studying in the two departments was very similar: both departments offered opportunities for research, in-class projects, creative and analytical thought, and real world problem solving. That said, **I never felt nearly as comfortable in the Math department as I did in Engineering**. "
- "Don't discount the positive effect of the **TA problem sessions** (both attending and becoming a TA later in school)."
- "Having everyone from the secretary to the janitor **encouraging** you makes more of a difference than you might think."
- "I can't say enough good things about the **flexible, interdisciplinary** focus and the unique worldview it provides students, and I would guess that this strength is a key reason the student body is so diverse."

- **"Hands-on projects, machine shop, and team experiences** were key for me. It's scary when the all the guys in your class already know what a rear differential is from working on cars/models, etc... but the early and often project approach got me caught up fast."
- **"Advising** is HUGELY important and influential in studying engineering... but I got very little of it."

Conclusions

Based on data collected through surveys, interviews and course enrollments, key aspects of the engineering program at Dartmouth that seem to have resulted in a more diverse student body with respect to gender include the community/atmosphere, supportive faculty, staff and peers, interdisciplinary, project-based learning, multiple entry points, and the introductory engineering course (ENGS21).

- **Community/Atmosphere**. Female students rated *atmosphere* as the highest factor influencing their decision to study engineering. What is it about the atmosphere that is so appealing? Things that emerged from interviews and surveys as being appealing about the atmosphere were the physical open spaces, collaborative group projects, and the evening problem sessions. The engineering building, which is open 24/7, includes many student work spaces such as the one shown in Figure 8. These work spaces seem to be constantly filled with students building prototypes and working on projects and problem sets. Teaching assistants (and some faculty) typically hold multiple evening problem sessions each week to help with projects and problem sets. These optional sessions are typically very well attended and provide opportunities for students to work collaboratively and with near pears. These optional sessions resemble the supplemental instruction model developed at the University of Missouri-Kansas City as the sessions are focused on high-risk courses, are peer-led, follow a regular schedule and meet outside of class [5]. Most of the projects at Dartmouth are group-based and collaborative and this may contribute to the fact that there are more women in engineering at Dartmouth since women tend to prefer a collaborative to a competitive atmosphere [6], [7].

Figure 8. Students working in the Couch Project Lab

- **Supportive Faculty, Staff, and Peers**. Female students also rated *caring faculty and staff* as a key factor influencing their decision to study engineering. A small group of high-touch faculty were identified by students as having a positive impact on them, the

majority of these faculty members who were identified are in non-tenure track positions. While the authors are not advocating for hiring non-tenure track faculty, it may be time to look at different reward structures for faculty such that supporting undergraduate students is a higher priority. We believe that a large part of the caring environment at Dartmouth comes from undergraduate peer mentoring, which as discussed above follows a supplemental instruction model [5]. Undergraduate teaching assistants, a high percentage of whom are female at Dartmouth, work directly with fellow undergraduates in group settings through problem sessions and support outside the classroom. A recent study found that female peer mentors have a large impact on the attitudes and retention of female students [8].

- **Interdisciplinary Project-Based Learning.** The engineering school at Dartmouth does not have departments, in part because it is a fairly small engineering school but also in part because the non-departmental structure allows faculty and students to more easily tackle real-world, interdisciplinary problems. Most courses include a group-based project that involves building prototypes, interacting with users, design, and presentations. The project-based curriculum goes beyond the technical details to include non-technical issues associated with authentic problems. A recent meta-analysis that included 225 studies found that student performance and retention in STEM courses increased when active learning strategies were used [9]; project-based learning is just one form of active learning. Student performance on exams was found to be 6% higher when active learning was used and students in courses that included active learning were 1.5 times less likely to fail the course [9]. Other studies support the finding that active learning results in improved engagement in engineering and across disciplines [6], [10], [11].
- **Multiple Entry Points**. The engineering curriculum at Dartmouth includes many courses for non-majors, giving students the opportunity to explore engineering before committing. Students at Dartmouth do not declare a major until they are sophomores, thus giving them time to explore different options. In addition, the curriculum is fairly flexible and customizable.
- **ENGS21**: *Introduction to Engineering* (ENGS21) is a hands-on, project-based course through which small groups of students collaborate to tackle real-world problems, generate solutions, and build prototypes. Problems that students tackle in the course are identified by the students themselves. In addition, all students in the course are taught a set of engineering skills that includes model building, tool and machine use, and computer-aided design. A NSF study that was completed in 2007 entitled *Investigating the Gender Component in Engineering* [12] studied factors that promote interest in engineering among undergraduate women at several institutions, including Dartmouth. Elements of the culture and courses at Dartmouth that were identified by Craemer's study [12] to promote interest in engineering among women included the use of a collaborative problem-solving approach, flexibility in the curriculum, focus on real world problems with social significance, and the interdisciplinary nature of projects. Craemer [12] identified *Introduction to Engineering* (ENGS21) as a pivotal course in the curriculum for generating interest among students, especially women.

While there is no easy answer to the question of how to achieve gender parity, they are some simple steps that may be taken at other schools to increase gender diversity including:

- Hiring female students to serve as teaching assistants and mentors,

- Focusing on interdisciplinary, project-based, student-driven projects, and
- Offering courses for non-majors.

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Appendix A. Student and Alumni Survey

Overview: The goal of this survey is to determine what draws students to engineering and what keeps them in engineering so that we may continue to attract and retain a diverse student body. Your participation is voluntary. All responses will remain anonymous. This survey is based on one developed by the AWE Program at Penn State (https://www.engr.psu.edu/awe/).

List three words that you would use to describe engineering at Thayer:

_____ _____ _____

List any faculty or staff members at Thayer who have had a positive impact on you:

_____ _____ _____

Are you considering majoring in engineering?

_____Yes _____ No _____ Maybe

If you are considering majoring in engineering, why are you considering it? (Check all that apply)

- ☐ Attracted by the challenge of a difficult curriculum
- ☐ Good at math or science
- ☐ High school advisor or teacher recommended it
- ☐ Like to solve problems
- ☐ Like the design work that engineers do
- ☐ Took an engineering course at Thayer that I enjoyed (please specify): _____
- ☐ Participated in an engineering camp or workshop that influenced me
- ☐ Parent, relative or friend is an engineer and recommended it
- ☐ Want to be able to get a well-paying job after I graduate
- ☐ Want to use engineering to address societal problems
- ☐ Want to become an entrepreneur
- ☐ Not Sure
- ☐ Other:_____

If you are considering majoring in engineering, what year do you expect to graduate from Thayer and with what degree (AB, BE, MEM, MS, or PhD)?

_____

For each scale/row below rate where you feel **engineering at Dartmouth** falls between the two words listed by circling a number from 1 to 10:

Analytical	1	2	3	4	5	6	7	8	9	10	**Intuitive**
Everyone can Succeed	1	2	3	4	5	6	7	8	9	10	**Specific Traits Required**
Conventional	1	2	3	4	5	6	7	8	9	10	**Creative**
Structured	1	2	3	4	5	6	7	8	9	10	**Flexible**
Science-Related	1	2	3	4	5	6	7	8	9	10	**Art-Related**
Applied	1	2	3	4	5	6	7	8	9	10	**Theoretical**

The following table lists factors associated with student interest in engineering. For each factor, mark **No Influence**, **Small Influence**, **Moderate Influence** or **Significant Influence** to indicate the degree to which that factor influences or influenced your interest in engineering.

	No Influence	Small Influence	Moderate Influence	Significant Influence
Opportunities to collaborate				
Many engineering courses are project-based				
Projects tend to be open-ended				
Courses and projects tend to be interdisciplinary				
Opportunities to do research				
Design and creativity are encouraged				
The engineering curriculum goes beyond the technical details to include the liberal arts				
Faculty and staff role models are present				
Faculty and staff care about students				
Time to explore options before declaring a major				
The curriculum is flexible and customizable				
The climate at Dartmouth is collaborative rather than competitive				
Opportunities to study internationally				
Opportunities to address societal problems				
Teaching quality is high				
Advising is effective in helping guide students				
I was taught basic skills (e.g., prototyping, coding, and CAD) early in the curriculum				
The engineering curriculum is challenging				
My personal abilities 'fit' at Thayer				
I've had positive experiences on project teams				
Other (please specify):				

How important is it to you that the Dartmouth community be diverse with respect to gender, ethnicity, socio-economic status, etc.?

Very Unimportant	Unimportant	Important	Very Important

What is your gender identity?

Male	Female	Other

Comments:

Appendix B. Faculty Survey

List three words that you would use to describe engineering at Dartmouth:

_____ _____ _____

How important do you think the following aspects have been in helping to diversify Thayer?

	Very Important	**Important**	**Unimportant**	**Very Unimportant**
Students have opportunities to collaborate				
Many engineering courses are project-based				
Projects tend to be open-ended				
Courses and projects tend to be interdisciplinary				
Students have opportunities to do research				
Design and creativity are encouraged				
Non-majors may take courses in engineering				
The engineering curriculum goes beyond the technical details to include the liberal arts				
Faculty and staff role models are present				
Review boards are diverse				
Faculty and staff care about students				
Students have time to explore different options before declaring a major				
The curriculum is flexible and customizable				
The climate in engineering courses is collaborative rather than competitive				
Students have opportunities to study internationally				
Students have opportunities to address societal problems				
Teaching quality is high				
Advising is effective in helping guide students				
All students are taught basic skills (e.g., prototyping, coding, and CAD) early in the curriculum				
The engineering curriculum is challenging				
Other (please specify):				

For each scale/row listed rate where you feel **engineering at Dartmouth** falls between the two words listed by circling a number from 1 to 10:

Analytical	1	2	3	4	5	6	7	8	9	10	**Intuitive**
Everyone can Succeed	1	2	3	4	5	6	7	8	9	10	**Specific Traits Required**
Conventional	1	2	3	4	5	6	7	8	9	10	**Creative**
Structured	1	2	3	4	5	6	7	8	9	10	**Flexible**
Science-Related	1	2	3	4	5	6	7	8	9	10	**Art-Related**
Applied	1	2	3	4	5	6	7	8	9	10	**Theoretical**

How important is it to you that the Dartmouth community be diverse with respect to gender, ethnicity, socio-economic status, etc.?

Very Important	**Important**	**Unimportant**	**Very Unimportant**

What is your gender identity?

Male	**Female**	**Other**

Have you taught undergraduate or BE courses in the past 2 years?

_____Yes _____ No

Comments: