Getting to Gender Parity in the Mechanical Engineering Department at MIT

by
Kathleen L. Xu

Submitted to the Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science in Mechanical Engineering
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Abstract

Consistently ranked as home to one of the world's top engineering programs, the Massachusetts Institute of Technology (MIT) is often seen as a model for its undergraduate education programs and research output. But MIT leads in another important way: the Institute also boasts one of the most gender-balanced STEM-oriented undergraduate student bodies in the world.

The purpose of the study was to help illuminate how the Mechanical Engineering Department in particular has reached near parity in its female undergraduate population: in 2015, females composed 46.4% of declared mechanical engineering majors. This study's approach was twofold: first, the gender enrollments in the largest mechanical engineering elective classes over the past 15 years were analyzed to determine differences, if any, in the subfields that female and male students choose to devote further study to. Second, a cross section of mechanical engineering faculty and staff were interviewed to evaluate how the department has changed over a similar timespan to make the place a much more welcoming place for women now.

The data analysis revealed that a larger fraction of undergraduate males in the department take the robotics and the controls classes than females do, but an increasing fraction of females in the department have taken the robotics class over time. The interview analysis presented several factors that contributed to the gender parity in the department over time, including changed hiring practices, role modeling, and careful attention to classroom dynamics. Ultimately, it is hoped that the findings in this thesis can help both the department and other institutions continue their paths to greater gender balance in their engineering programs.

Thesis Supervisors: Dawn Wendell, Andrea Walsh
Titles: Senior Lecturer, Lecturer II

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To all of my interviewees—Peko Hosoi, Warren Seering, Mary Boyce, Barbara Hughey, Doug Hart, Betar Gallant, Rohan Abeyaratne, Maria Yang, Stu Schmill, and Brandy Baker—for sharing your lives and wisdom with me and with the rest of the department. MechE is a better place to be with all of you.

And last, but not least, to my parents for making it possible for me to attend this place and earn a degree from MIT.

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1. Introduction

1.1 Motivation

Like the set of theses that have come before mine, this thesis aims to bridge the gap between women's and men's experiences in engineering. Although the undergraduate female representation in engineering has been steadily increasing at MIT, that in and of itself hasn't necessarily translated into equal experiences (Chin and Tekiela). Since I am an undergraduate mechanical engineering major and a women's and gender studies concentrator, the topic area itself was a clear choice. What exactly to study, however, was not so easy to determine.

Early on, my thesis advisers and I decided that in the interest of time, it was best to choose between conducting a survey and conducting interviews. While we ultimately chose to go with interviews to receive an in-depth look with a representative cross section of the department, designing a survey would be the logical next step as a follow-up to the points made in this thesis.

Likewise, several data sets were considered before settling on the final choice: the first choice was a comparison of the average grades of female and male students in undergraduate mechanical engineering classes to evaluate the discrepancy, if any, between the academic performance of the two genders. Ultimately, the department chose not to release this data, so we considered other potential data sets—the gender composition of 2.009 (Product Engineering Processes)[1] project leaders over the years, class office hour attendance, undergraduate thesis topic areas, and class participation rates, to name a few.

While those were all interesting, we decided to take a closer look at the mechanical engineering elective classes. Because these are classes that students are able to choose, unlike the core classes, the choices made should help illuminate where people's preferences lie—and if there exist subtle gender dynamics that push and pull people away from certain classes.

Hence, this thesis is divided into two parts: the first part will break down the elective classes data and the second part will delve into in-depth interviews with key members of MIT's Mechanical Engineering (MechE) Department.

[1] 2.009 is often considered the senior capstone class of the undergraduate mechanical engineering major at MIT.

1.2 Research Questions

From the data:
When given a choice, which elective classes do female and male MIT MechE students tend to gravitate towards? Do female and male students lean towards different areas? If so, have these trends changed over time?

From the interviews:
What differences have instructors noticed when it comes to gender dynamics in the mechanical engineering department at MIT? In what ways do they think the department could be improved? How have their personal experiences shaped where they are today? In what ways can we draw more women into engineering in general?

2. Background

2.1 Women in Mechanical Engineering

According to a 2014 report by the American Society for Engineering Education (ASEE), women earned 19.5% of engineering bachelor's degrees in the United States that year (Yoder). However, the percentage of degrees earned by women varies widely based on the engineering discipline.

Mechanical engineering is the most popular bachelor's engineering degree in the U.S., claiming almost a quarter of all engineering degrees. However, only 13.5% of mechanical engineering bachelor's degrees went to women in the 2013-2014 year, making it one of the most gender-imbalanced engineering disciplines in the U.S. (Yoder).

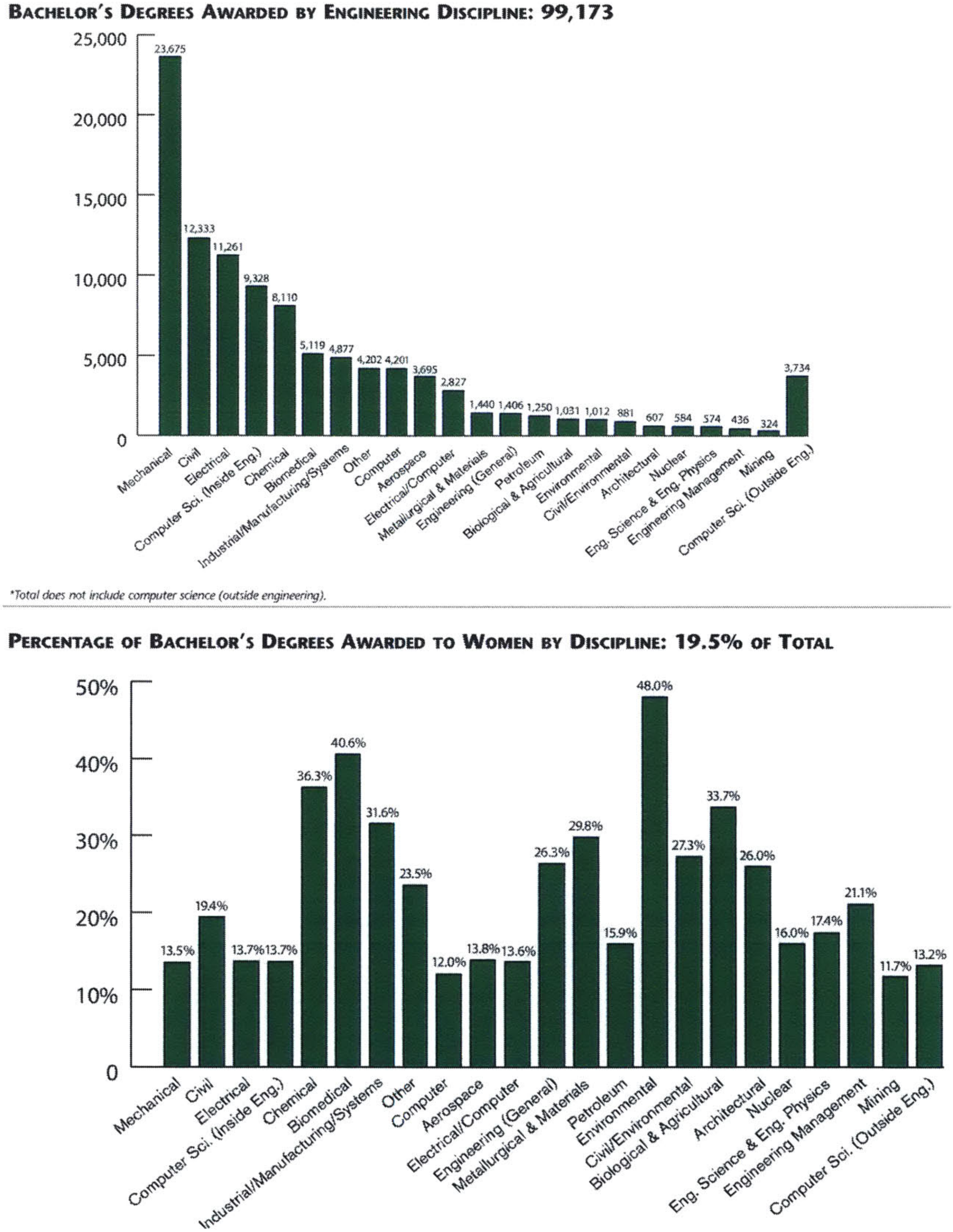

Figure 1: A breakdown of engineering degrees awarded by popularity (top) and gender (bottom) in the United States in 2014 (Yoder).

2.2 MIT's Mechanical Engineering Department

MIT's Department of Mechanical Engineering (sometimes referred to as Course 2 or MechE) began as one of the six founding majors in 1865 and became an official department in 1883 ("MechE History and Timeline").[2] At the time, specializations such as locomotive engineering and mill engineering were offered. In the early 1930s, aeronautic concepts began to be incorporated into the mechanical engineering curriculum, and the traditional hydraulics course turned into a more general fluids mechanics course, which is still taken today in two parts. The mid-1960s marked a departmental shift in research focus from military applications to so-called quality of life applications, such as biomedical and environmental engineering.

Today, the research focuses on seven main areas: mechanics, design, controls, energy, ocean, bioengineering, and nanotechnology. The undergraduate department offers three tracks: standard 2, 2A, and 2OE[3]. While building upon a similar base as Course 2's traditional curriculum, 2A and 2OE students are given more flexibility to allow them to pursue specializations at a deeper level. Sample tracks for 2A include biomedical devices, energy, engineering management, and industrial design. 2OE students, of course, concentrate in ocean engineering.

The department's official website bills 2A as "one of the first mechanical engineering programs in the world to offer a customizable curriculum alongside a rigorous core in mechanical engineering and the ability to concentrate in one of several modern engineering areas" ("Undergraduate Course 2-A Program").

In 2002, 2A received accreditation from the Accreditation Board for Engineering and Technology ("MechE History and Timeline"). Since then, the number of students who have declared a major in 2A have risen dramatically, as can be seen in Figure 2 on the next page.

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[2] The other five majors were a "General" Course, Civil and Topological Engineering, Geology and Mining, Architecture, Practical and Technical Chemistry, and Mechanical Construction Engineering.

[3] Where OE stands for ocean engineering.

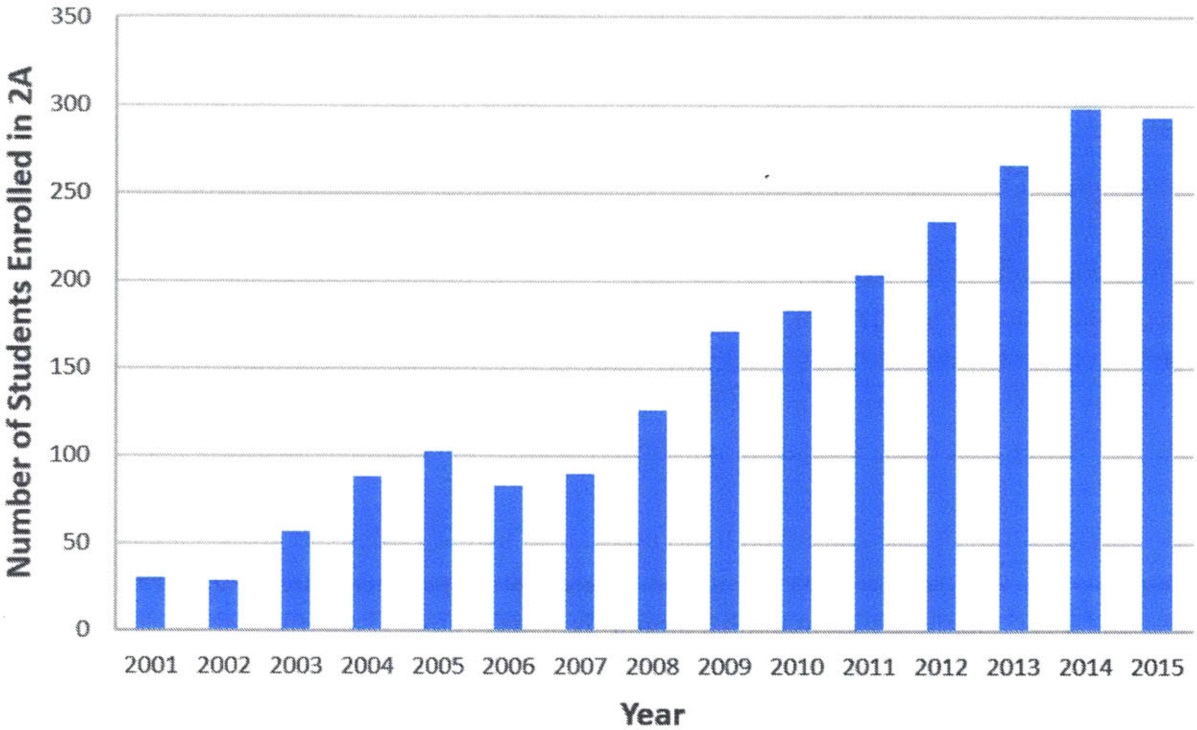

Figure 2: The number of students in 2A has increased significantly since accreditation in 2002.

In 2005, the Department of Ocean Engineering merged with the Department of Mechanical Engineering and students taking an ocean engineering track then fell under the designation 2OE.

MechE has been one of the largest departments at MIT for a while, second only to the Department of Electrical Engineering and Computer Science (Satish). In 2015, 16.6% of students at MIT declared mechanical engineering as their major,[4] 45.2% of whom chose standard 2, 52.5% 2A, and 2.3% 2OE.

2.3 Brief History of Women at MIT

Before we explore the topic of women in MechE at the Institute, we need to review the history of women at MIT in general. MIT, unlike many other American institutions of higher learning, has never explicitly forbidden women from entering the Institute. MIT graduated its first class in 1868, and admitted its first woman, Ellen Swallow Richards, two years later in 1870 as a special student ("Ellen Swallow Richards and MIT"). However, the Corporation, MIT's governing body, took care to confine its decision to only her case, and wrote that Swallow's admission "did not

[4] Taken as the fraction of declared standard 2, 2A, and 2OE majors over the total number of students with declared majors in the Fall 2015 term (i.e. years 2, 3, 4, and 5).

establish a precedent for the general admission of females." Swallow later also became MIT's first female teacher after graduating in 1873 with a degree in chemistry.

While MIT would continue to admit more women over the years, the numbers would generally remain paltry (less than 3%) into the mid-20th century—at which point MIT actually considered closing its doors to women altogether in 1956. As Iowa State History Professor Amy Sue Bix wrote in her 2014 book *Girls Coming into Tech*, "Critics also worried that MIT's inherent character as a masculinized technical environment inevitably twisted the proper femininity of the few women who chose to attend… MIT's medical director praised the 'healthy' aggressive drive of MIT's 'well-adjusted men' but associated competitiveness in women with a rejection of femininity" (227).

Thankfully, the President of MIT at the time, James Killian, decided to listen to the minority who rejected this claim and to welcome women with open arms instead. Parity, however, certainly would not be able to be achieved without a larger percentage of women. According to the theory of critical mass in gender politics, only when a certain percentage of women (usually set to 30%) is reached do women gain the ability to start making a meaningful impact, whether in corporate boardrooms, legislatures, or other settings (Troiano). This percentage would be a long time coming.

As Bix wrote, "In the late 1950s, the few female undergraduates at MIT felt afraid to rock the boat by demanding too much. Christina Jansen, who received a bachelor's degree in electrical in 1963 (and later returned to MIT for her master's and doctorate), recalled, 'I was really very conscious of having to represent women in each class. If I did anything wrong, if I said anything stupid, it would be ammunition for all the men who didn't want us to be there in the first place'" (229).

To encourage more women to attend MIT, the school opened McCormick Hall in 1963, which had the capacity to house 116 women, thanks to a generous donation by Katharine Dexter McCormick (MIT Class of 1904). Previously, the only residence available was a women's house at 120 Bay State Road in Boston. Unfortunately, this place could accommodate only 14 new women each year, which effectively became a quota.[5]

The opening of McCormick Hall was heralded in the media, with coverage from *Time* magazine to *Seventeen* magazine, even though *Time* "paid more attention to Tech women's preferences in boyfriends than to their preferences in classes" (Bix 230). Part of the motivation arose from the

[5] This number does not include an unspecified number of married and commuter female students.

desire to compete with the Soviet Union with technology and the need to tap into all of society—not just half.

According to Bix, "Such publicity surrounding the opening of McCormick Hall alerted many members of the public for the first time to the fact that MIT accepted women" (231). In the next year, 1964, "the number of female undergraduate applicants jumped to four hundred, up about 50 percent from the 1959 to 1963 level of about 275" (Bix 231).

Then, in one decade, the percentage of women in the freshman class jumped from about 5% in 1965 (48 out of 958 students) to about 20% in 1974 (211 out of 1,036 students) (Bix 248). Now, MIT's freshman class (the Class of 2019) is 47% female and 53% male ("Freshman Class Profile").

Unfortunately, though, it seems that women still face different experiences at the Institute. According to the 2014 Community Attitudes on Sexual Assault (CASA) survey, almost half of the female survey respondents reported facing a social setting experience that "suggested or implied women don't have to meet the same intellectual standards men do to get into MIT" ("Survey Results").

Nevertheless, according to the MIT Registrar, females on average graduate with slightly higher grade point averages (GPAs) than males, even when controlling for the chosen major (Chin and Tekiela).[6] Moreover, women's graduation rates have consistently exceeded those of men, as can be seen in the below table:[7]

Table 1: Six-year graduation rates by gender from 2003-2008 ("Retention and Graduation Rates").

	Fall Cohort year					
Gender	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Men	90%	91%	91%	92%	91%	90%
Women	93%	96%	95%	93%	95%	92%

While female undergraduates may have reached near parity in numbers, the story is very different for female faculty members.

[6] Based on an analysis of final year GPAs between 2004 and 2011.
[7] http://web.mit.edu/ir/pop/students/graduation_rates.html

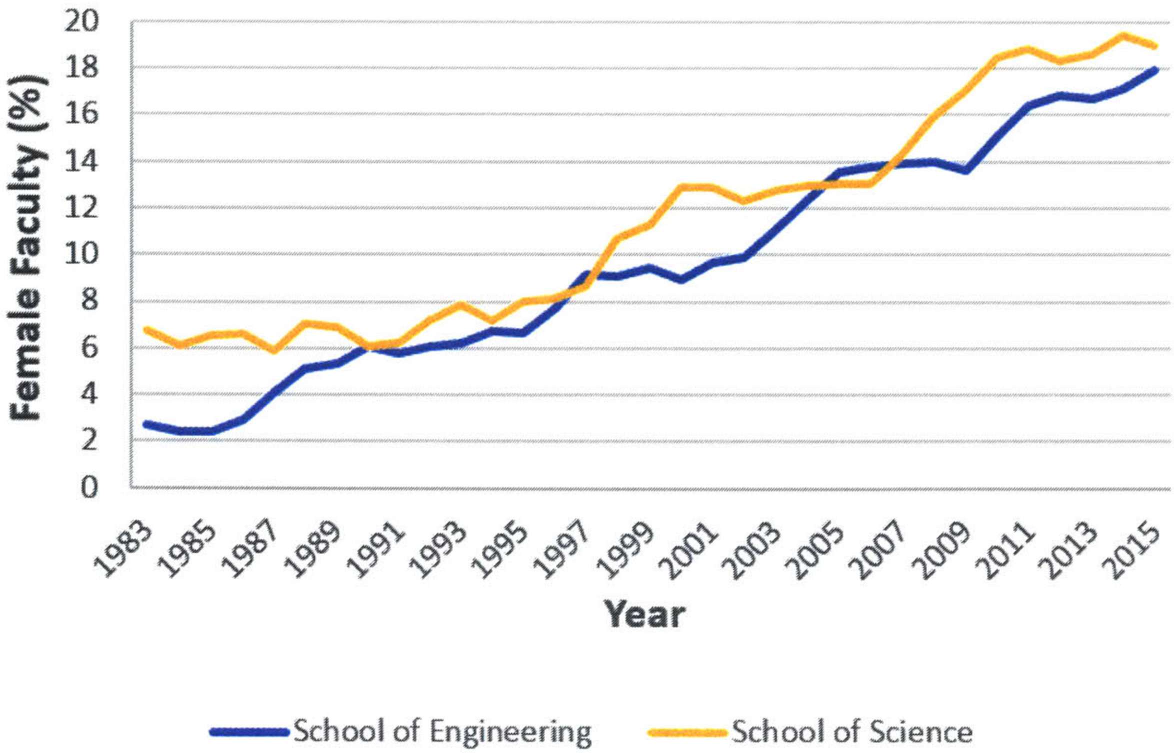

Figure 3: The percentage of female faculty at MIT in the School of Engineering and the School of Science.[8]

The percentage of female engineering faculty at MIT has increased from 9.0% in 2000 to 18.0% in 2015, likely driven at least in part due to the 2002 "Report of the School of Engineering," which highlighted the barriers that female faculty in particular still faced at MIT.

According to the "Report on the Status of Undergraduate Women at MIT" (SUWM), "the lack of female faculty members and advisors was a major theme across all focus groups. An undergraduate physics major said, 'I had a choice of 12 male advisors. If there was even one woman there, she would have been the one [I would have chosen].' In one of the November focus groups an undergraduate in computer science said that because of the limited number of female professors, 'It's hard to see myself as a computer scientist. It's hard to see myself doing it in my future'" (Chin and Tekiela).

Perhaps influenced by the lack of role models in certain fields, female undergraduate students tend to self-select into departments differently. On the low end, the Department of Physics is currently 30.0% female, Mathematics 31.9%, and Electrical Engineering and Computer Science 39.2%. On the high end, the Department of Bioengineering is 69.5% female, Biology 74.5%,

[8] The data, as provided by MIT's Director of Institutional Research, Lydia Snover, can be found in the appendices.

Earth, Atmospheric, and Planetary Sciences 80.0%, and Brain and Cognitive sciences 81.9% ("Number of Women Students").

2.4 Women in MIT's Mechanical Engineering Department

Given the context of the mechanical engineering field and the history of women at MIT, we can now take a closer look at the intersection of the two—the state of women in the MechE department at MIT.

2.4.1 Faculty

MIT's Mechanical Engineering Department hired its first female faculty member, Mary Boyce, in 1987 (Boyce et al. 12). According to former department head Rohan Abeyaratne, the MechE department used to be known as a department that was "unfriendly" to females.

While four other women were hired between 1987 and 2000, only Boyce remained at MIT past tenure (Boyce et al. 12). In 2002, the Committee on the Status of Women Faculty found that a "much higher percentage of female job candidates reject offers to come to MIT—40% of women compared with 14% of the men offered jobs. Given MIT's status as one of the premier research universities in engineering in the world, these results are disturbing" (Boyce et al. 7). Discrepancies were also found in salary, compensation, and academic duties such as teaching loads and committee memberships.

Now, in 2016, there are six female tenured professors in the department ("Faculty Profiles").[9]

2.4.2 Undergraduates

While the percentage of undergraduate women at MIT as whole has stayed fairly constant over the past 15 years, the percentage of undergraduate women in mechanical engineering has increased dramatically over the past decade and a half, from a low of 32.5% in 2002 to a high of 46.8% in 2014.

[9] These are Domitilla Del Vecchio, Yang Shao-Horn, Peko Hosoi, Alexandra Techet, Evelyn Wang, and Maria Yang.

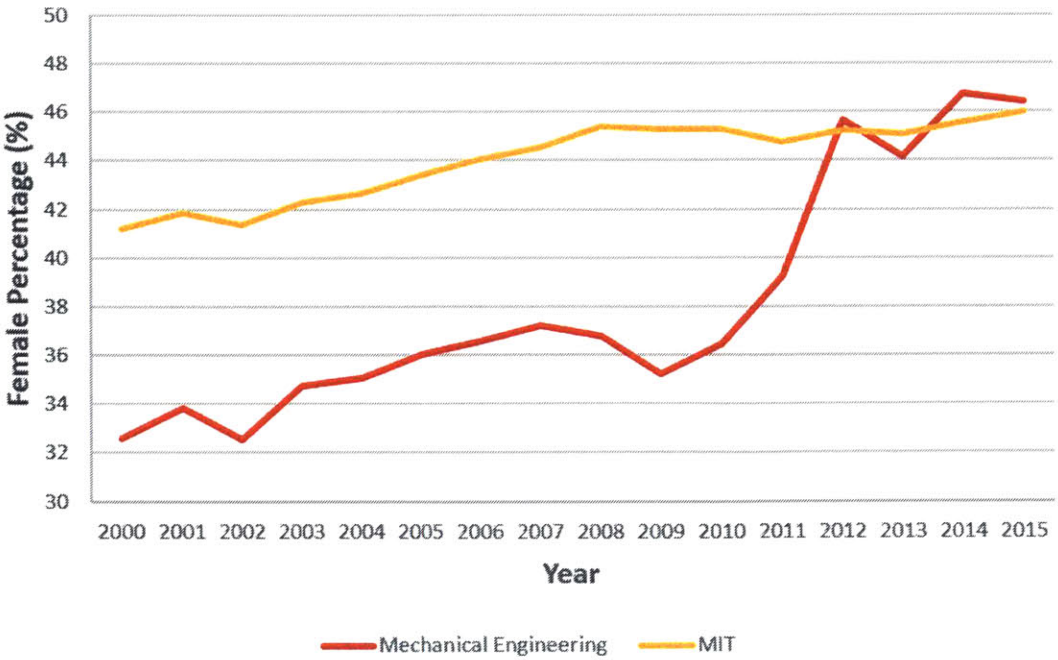

Figure 4: Percentage of declared female majors (sophomore, junior, senior, and super-senior students) in the Department of Mechanical Engineering (2, 2A, and 2OE) over time, compared to the percentage of undergraduate female students at MIT.

The largest jump in the MechE department occurred over a three-year period between 2009 and 2012, with an increase from 35.2% to 45.7%.

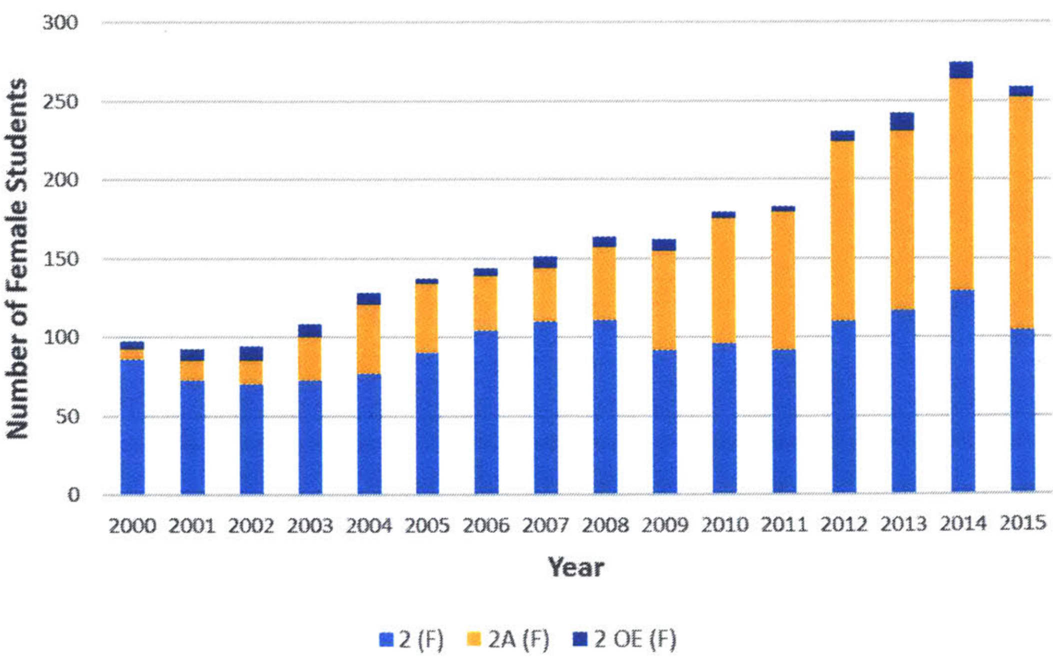

Figure 5: Breakdown of female composition in standard 2, 2A, and 2OE over the years.

As the number of students in 2A has grown, so has the number of female students in that track, bringing up the total number of female students in the department. However, 2A itself is not heavily female, as is perhaps commonly perceived in the department. 2A has only recently reached a balanced gender ratio of 50.5% female and 49.5% male in 2015. For the ten years prior, the ratio had consistently skewed more towards males, with a low of 36.5% female in 2008.

It is important to note that this is not a national trend. According to the Spring 2016 Term at Georgia Institute of Technology, females compose only 21.1% of the total undergraduate mechanical engineering majors ("Enrollment by Major"). For the 2015-2016 academic year at the California Institute of Technology, females compose 30.6% of the total undergraduate mechanical engineering majors.[10]

What makes MIT different? Why did these jumps occur? How did MIT's mechanical engineering department get to where it is today? Does the gender balance equalization in the department's enrollment correspond with equalization in the MechE elective enrollments as well?

This thesis aims to help answer these questions through an in-depth look at the data and interviews.

[10] A full data set, as provided by Caltech's Registrar Office, can be found in the appendices.

3. Data Methods

The original data set for this thesis was obtained from MIT's Office of the Registrar in January 2016, with the following specifications:

- Number of female and male students in each of the following standard 2 elective classes:
    - 2.016, 2.017, 2.019, 2.050, 2.092, 2.12, 2.14, 2.184, 2.370, 2.51 2.60, 2.650, 2.71, 2.72, 2.797, 2.813, and 2.96
- Time span: Fall 2000 to Spring 2015
- To obtain the most accurate data, listeners or students who dropped the class were not included. The final counts came from the end of the term.
- Although the actual class enrollments were not restricted to undergraduate department majors, only mechanical engineering undergraduate students were included in this data analysis.[11] For alumni, this meant the major at the time of graduation. For current students, this meant their current major as recorded by the Registrar.

The result was two sets of Microsoft Excel files, one, which contained a list of each class by term with the number of female and male students, broken down into standard 2, 2A, and 2OE undergraduates, and another file, which contained a list of each class by term with their respective total enrollments (including non-mechanical engineering students).[12]

To obtain the most statistically significant results, only the classes with the highest four enrollments over the years were selected for the data analysis:

- 2.12 (Introduction to Robotics)
    - Data beginning from Fall Term 2004
    - 2.12 is a popular class for any MIT mechanical engineering undergraduate interested or potentially interested in going into robotics after graduation. A team competition at the end of the term usually requires students to build a robotic system that can complete a set of tasks. 2.004, Dynamics and Controls II, is a prerequisite. The graduate version of this class meets at the same time.
- 2.14 (Analysis and Design of Feedback Control Systems)
    - Data beginning from Fall Term 2002

[11] Whenever this section refers to "students" and calculates percentages or total enrollments from here on out, only undergraduate mechanical engineering students are included in the description.

[12] Terms were indicated by academic year, so "2005FA" on the spreadsheet would correspond to the fall term of academic year 2004-2005, *not* the fall term of the year 2005. For the purposes of this data section, a class that was taught in "2005FA" is indicated as 2004. All four of the classes analyzed in this section were fall term-only classes.

    - 2.14 is the next step in the controls sequence of courses at MIT after 2.004, which is also a prerequisite for this class. The graduate version of this class meets at the same time.
- 2.72 (Elements of Mechanical Design)
    - Data beginning from Fall Term 2001
    - 2.72 is a project class for those interested in machines. After Professor Martin Culpepper took over teaching the class, the emphasis has swung heavily towards more hands-on building (Mallinson)—students now work in teams to build a working lathe by the end of the semester. Of the four classes, this one requires the most prerequisites, with 2.005 (Thermal-Fluids Engineering I) and 2.008 (Design and Manufacturing II), both of which require their own sequence of prerequisites.
- 2.96 (Management in Engineering)
    - Data beginning from Fall Term 2000
    - 2.96 is an introductory class that provides an overview of engineering management. According to the course description in MIT's course catalog, the classes focuses on "the development of individual skills and management tools." There are no prerequisites.

4. Data Analysis and Interpretations

The primary questions this section of the thesis aims to answer are:

1) What is the fraction of undergraduate women in the department who choose to take (and complete) the largest electives, i.e. $\frac{Females\ in\ Class}{Total\ Females\ in\ the\ Department}$?[13]
    a) How do these ratios vary over the years that the course has been offered?
    b) How do these ratios compare to the fraction of undergraduate men in the department who choose to take the courses?
2) Are women more drawn to one elective than to others? If so, which ones?

In forming these research questions, I anticipated that women and men would enroll in these elective classes at different rates. Of the four, I thought that the 2.96 management class would attract the most women, while the 2.14 controls class the least. In addition, I hypothesized that over time, each of the classes would see an increased percentage of women in the department who chose to take those classes, particularly in the 2.12 robotics class as it has become one of the most popular project classes in the major.

Recall from the background section that the undergraduate female percentage in the Mechanical Engineering Department and the number of declared undergraduate majors in the department have both increased significantly since 2009. I speculated that the more popular a class became, the more it would become a "de facto" major requirement, and thus the more equalized its gender enrollment would be as women and men viewed that class in a more gender-neutral light (whether subconsciously or consciously).

Statistically significant differences in enrollments between the elective classes seemed likely given that women are quite unevenly represented even within the STEM subfields themselves.

To answer these questions, the relevant data were culled, percentages and linear slopes computed, and paired t-tests performed. The first question and its subquestions are explored in Sections 4.1 and 4.2, while the second question is explored in Section 4.3.

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[13] Note that there is a difference between asking for the fraction of women in the department who choose to take a class and asking for the percentage of women in the class itself. The first question asks for "Females in Class / Total Females in Department," while the second question asks for "Females in Class / Total Students in Class." While the second question is also an interesting question to study, this thesis prioritized the first question over the second one, and so will give more discussion to the former. To distinguish the two results, the first will generally be called a "ratio" or "fraction," and the second a "percentage" in the text and the figure axis titles.

Ultimately, it is hoped that any illuminated differences can help bring attention to which subjects women are choosing more than others for future researchers to look at what may be driving any disparities.

4.1 Individual Class Gender Ratios

First, average female and male ratios were computed for each class based on enrollment data from 2004 to 2014 to get a sense of how the classes approximately compared to each other. (Statistically significant differences will be discussed in the subsequent sections when paired t-tests are performed.)

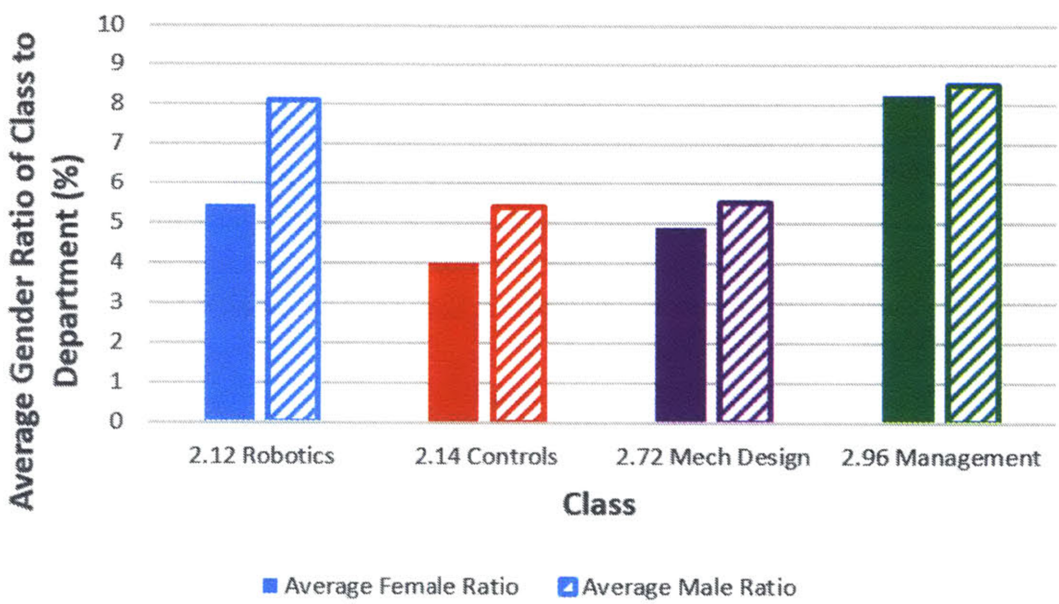

Figure 6: A comparison of the ratio of females in each class (2.12 robotics, 2.14 controls, 2.72 mechanical design, and 2.96 management) to the total number of females in the department during that year, averaged from 2004 to 2014. 2.96 had the highest female and male ratios with 8.2% and 8.5%, respectively, while 2.14 had the lowest with 4.0% and 5.4%, respectively. In all cases, the male ratios were higher than the female ones.

On average over that time span, the 2.96 management class saw double the female ratio (8.2%)[14] that the 2.14 controls class did (4.0%), although females and males seemed to have taken the 2.96 management class at comparable rates. The 2.12 robotics and 2.72 mechanical design classes had female ratios closer to 2.14 than 2.96. In all cases, the male ratios were higher than the female ones, although the difference was smallest for 2.96.

[14] Note that the ratio of the number women in the class to the number of women realistically available to take the class would likely be higher than these values, given that three of the classes (2.12, 2.14, and 2.72) have a large number of prerequisites that make them very difficult for sophomores to take. Moreover, most sophomores spend their first year in the major building foundations instead of taking elective classes, so 2.96 tends not to be a popular sophomore class either. Thus, the pool of available women to take these classes is reduced.

Next, each of the classes' gender ratios over time was reviewed separately, beginning with the 2.12 robotics class.

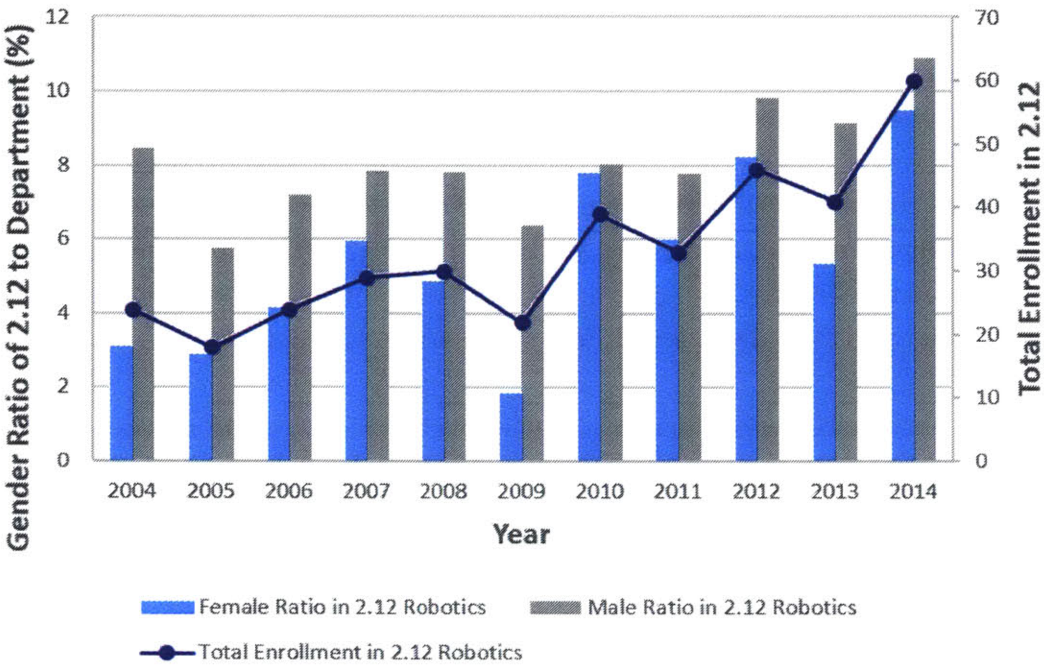

Figure 7: The fraction of undergraduate women in the Mechanical Engineering Department who take the 2.12 robotics class over time. The lowest female ratio (1.9%) occurred in 2009, and the highest (9.5%) in 2014.

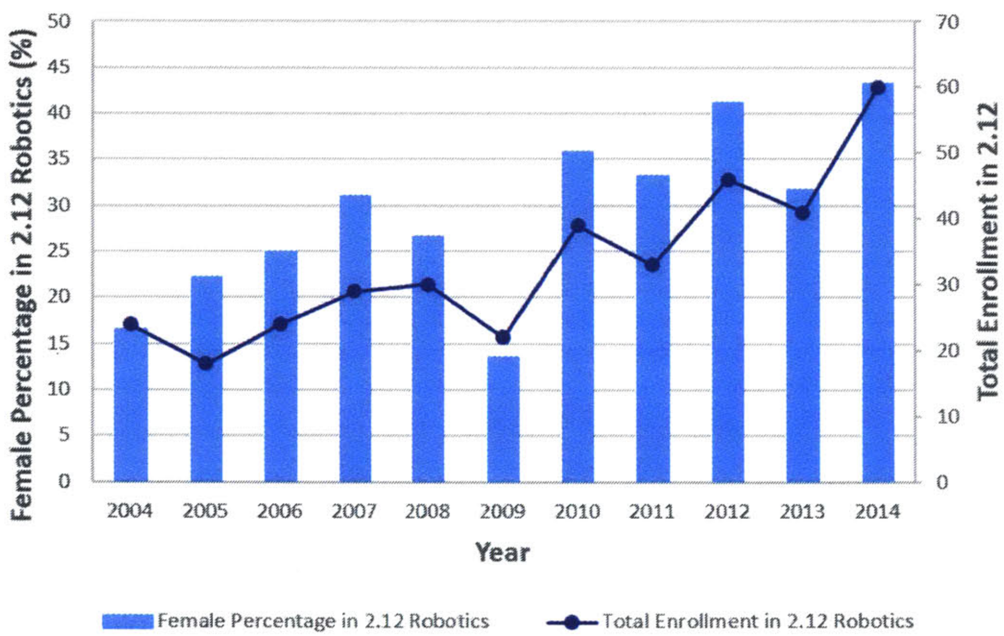

Figure 8: The percentage of women in the 2.12 robotics class over time. The lowest female percentage (13.6%) occurred in 2009, and the highest (43.3%) in 2014.

The ratio of gender in 2.12 to gender in the department can be seen in Figure 2, and the female percentage of the class over time can be seen in Figure 3.

It seems that a higher fraction of females have elected to take the 2.12 robotics class over time, although there was a dip in 2009 in both the total class enrollment and the female percentage of the class that year.

In addition, there was a disproportionate dip in the fraction of females that decided to take the class that year, as compared to the fraction of males. The eight females out of a class of 30 in the previous year dropped to three females out of a class of 22 in 2009. Despite the increase in women who are taking the class, the male ratios have still consistently been higher than the female ratios. 2009 was the only year that Professor Harry Asada did not teach the class.[15]

In an email response, Asada wrote that he, too, was "wondering why 2.12 was becoming popular among female students." He said that the class has always had a term project, so the class structure has not seemed to change significantly. Asada thought that one factor might be the increasing number of female founders and CEOs of robotics startups, such as those of iRobot, Vecna, and CyPhy.

While 2009 saw the lowest female ratio (1.9%), 2014 saw the highest (9.5%). This means almost one in ten women in the department was taking the class at the time.

The female percentage followed a similar trend over the years. Although the percentage has been generally increasing towards 50%, it has not yet reached it.[16]

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[15] The full instructor lists for each class, as provided by the department's undergraduate academic administrator Brandy Baker, can be found in the appendices.

[16] It is possible that the class reached 50% this past fall term, but the enrollment data from Fall 2015 were unavailable at the time that the Registrar was contacted.

Next, the enrollment data for the 2.14 controls class over time were analyzed.

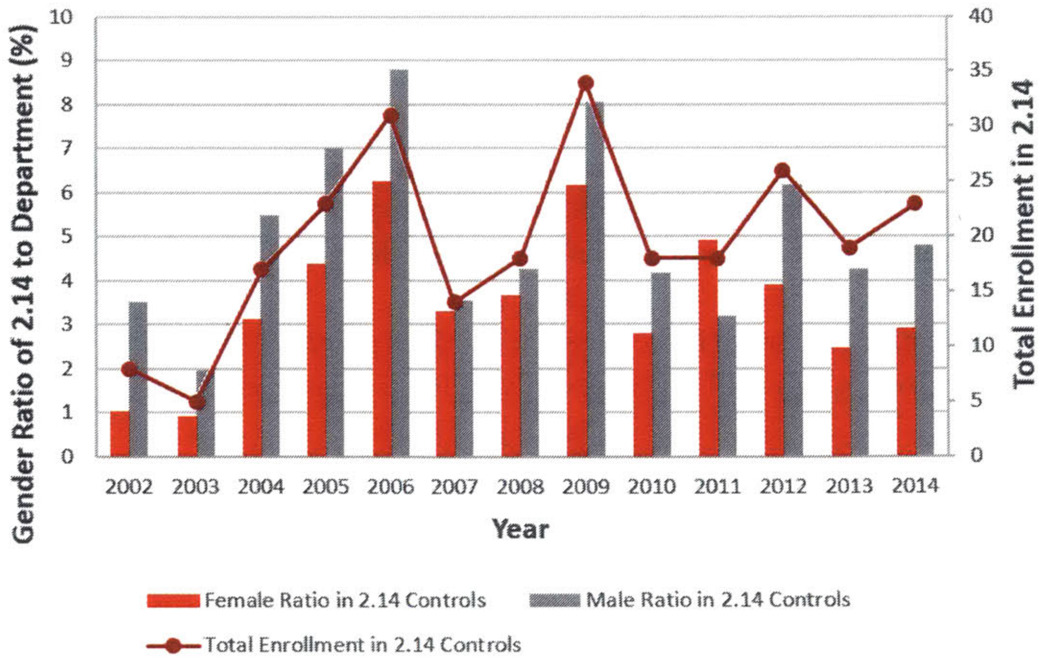

Figure 9: The fraction of undergraduate women in the Mechanical Engineering Department who take the 2.14 controls class over time. The lowest female ratio (0.9%) occurred in 2003, and the highest (6.3%) in 2006, but there were significantly more people enrolled in the class in 2006 than in 2003.

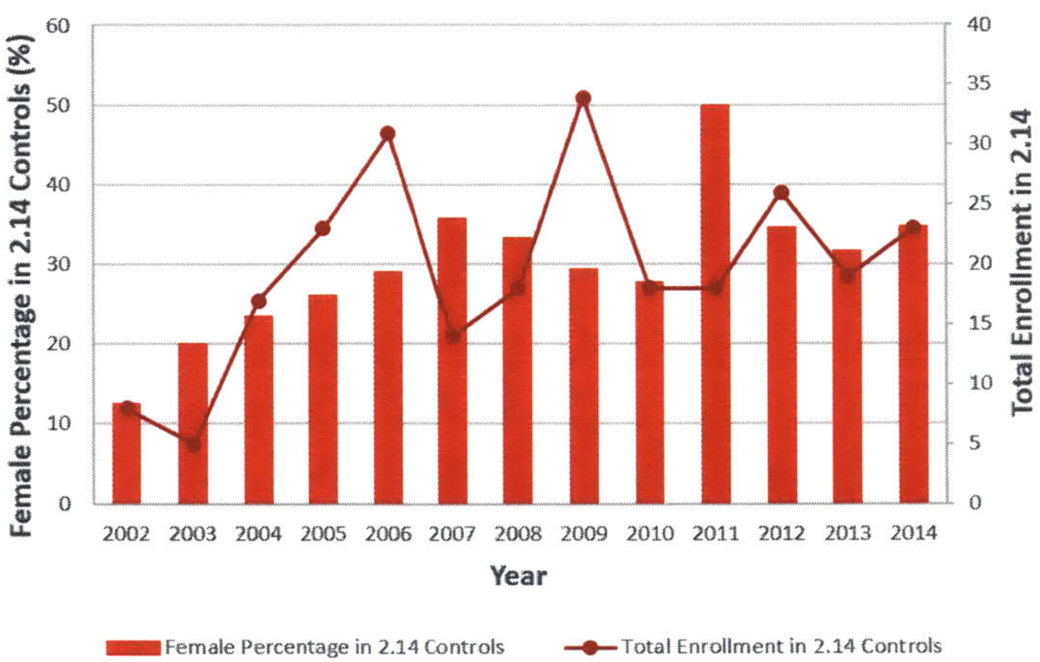

Figure 10: The percentage of women in the 2.14 controls class over time. The lowest female percentage (12.5%) occurred in 2002, and the highest (50.0%) in 2011.

The 2.14 controls class had low female ratios at the beginning years, but there were also very few undergraduate mechanical engineering students enrolled in the class at the time (eight in 2002 and five in 2003).

The fraction of male MechE undergraduates who take this class has almost always been greater than the corresponding female fraction, with the exception of 2011. Since 2006, instructors have alternated between Professors Kamal Youcef-Toumi, Jean-Jacques Slotine, and David Trumper.

In terms of the female percentage in the class, the class has generally been more male-dominated, except for in 2011, when exactly half of the class were female.

Next, the enrollment data for the 2.72 mechanical design class over time were analyzed.

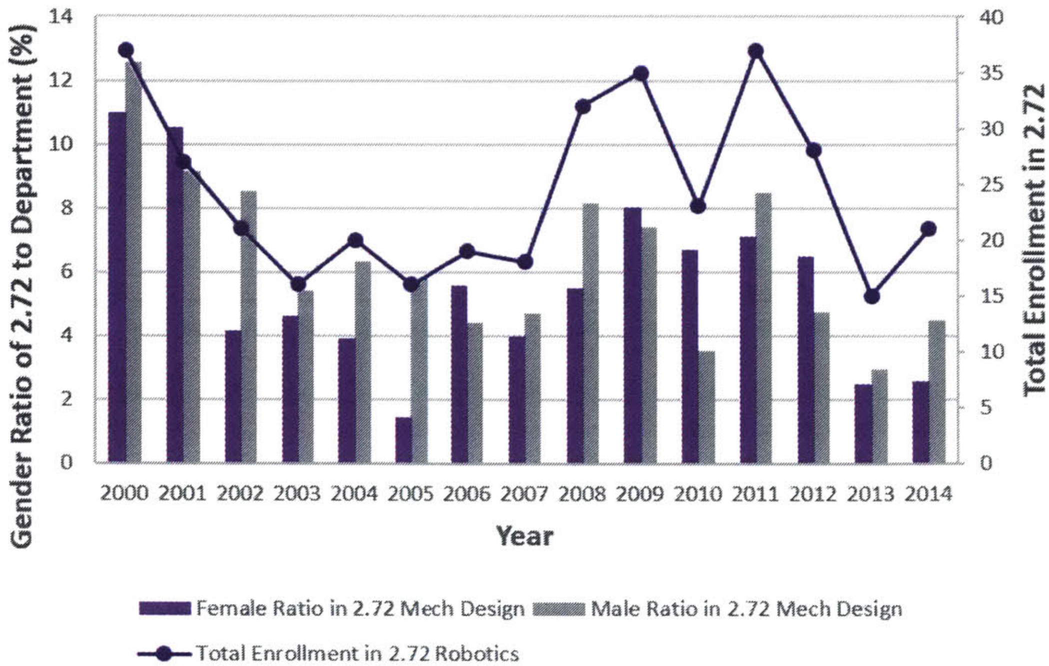

Figure 11: The fraction of undergraduate women in the Mechanical Engineering Department who take the 2.72 mechanical design class over time. The lowest female ratio (1.5%) occurred in 2005, and the highest (11%) in 2000.

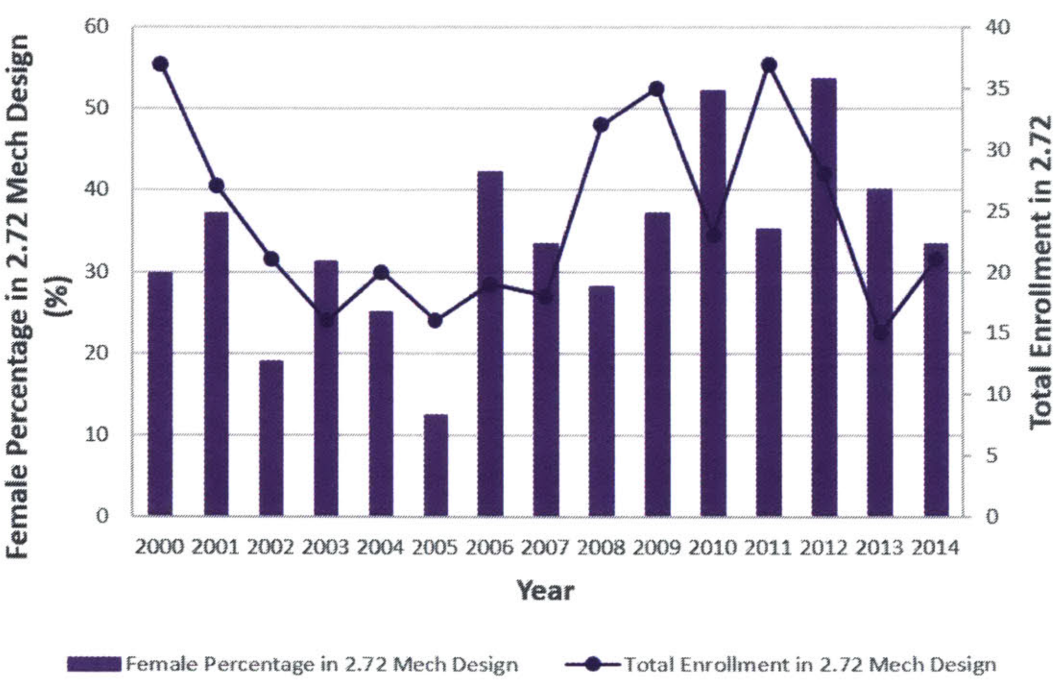

Figure 12: The percentage of women in the 2.72 mechanical design class over time. The lowest female percentage (12.5%) occurred in 2005, and the highest (53.6%) in 2012.

The 2.72 mechanical design class saw its highest female ratios in the beginning few years, while the lowest female ratio occurred in 2005, when only two female students took the class out of a total female count in the department of 137, resulting in a ratio of 1.5%.

Unlike 2.12 and 2.14, though, the male ratios for this class have not almost always been higher than the female ratios—in 2001, 2006, 2009, 2010, and 2012, a larger fraction of females in the department took the class than males did.

It is also important to note that the focus of the class depends heavily on the instructor, and has changed significantly over the years. In 2003, the class focused on medical devices, while in 2004, the students were asked to build a robot that could engage in a game of tug-of-war with another robot. Only when Prof. Martin Culpepper joined the course in 2007 did the emphasis turn to building precision miniature lathes, which is the focus now.

In terms of the female percentage in the class, 2.72 has exceeded the 50% mark two times, once in 2010 and again two years later in 2012. The lowest female percentage occurred in 2005, when only 12.5% of the class were female.

Finally, the enrollment data for the 2.96 management class over time were analyzed.

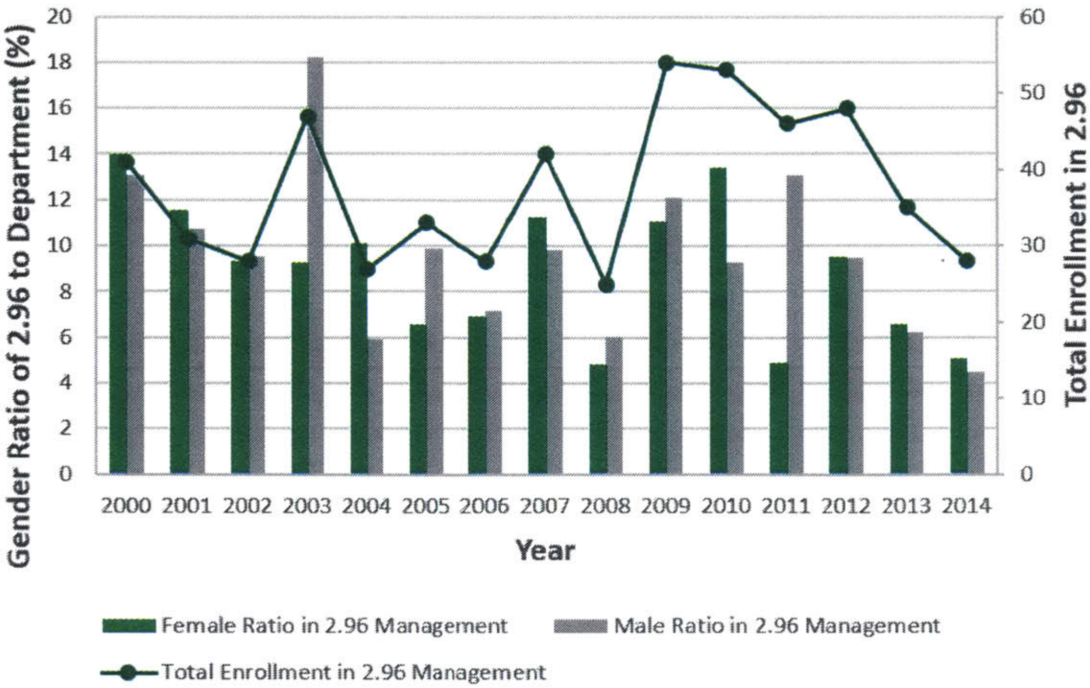

Figure 13: The fraction of undergraduate women in the Mechanical Engineering Department who take the 2.96 management class over time. The lowest female ratio (4.9%) occurred in 2008, and the highest (14.0%) in 2000.

Figure 14: The percentage of women in the 2.96 management class over time. The lowest female percentage (19.6%) occurred in 2011, and the highest (50.0%) in 2014.

The 2.96 management class had the largest variability[17] in female ratios over the years when comparing the classes across the same time span of 2004-2014.

The largest change in the fraction of women who chose to take 2.96 occurred between 2010, in which 13.4% of the undergraduate females in the department took the class, and 2011, in which only 4.9% of the undergraduate females in the department took the class (a drop of 8.5%).

In 2010, Professors Henry S. Marcus and Abbott Weiss taught the class, while in 2011, Professors Henry S. Marcus and Jung-Hoon Chun taught the class. Chun has taught or co-taught 2.96 for a majority of the years shown below.

Like 2.72, the male ratios for this class have not always been higher than the female ratios—in a little over half of the years of this data set, (2000-2001, 2004, 2007, 2010, and 2012-2014) a larger fraction of females in the department took the class than males did. However, the differences have almost always been small (oftentimes less than 1%).

It is interesting to note the particularly large spike in the fraction of males in the department who took the class in 2003. Almost one in five males in the department was in the class at the time!

In terms of the female percentage in the class, despite the fact that the female ratios have exceeded the male ratios over half of the time, women have only reached the 50% mark once, in 2014.

4.2 Paired T-Test Results for Individual Class Gender Ratios

Next, the female ratios were directly compared to the male ratios for each class using a paired t-test, a commonly used statistical test to determine if the means of two sets of data differ significantly from each other. The paired t-test was used because the two samples are correlated, since the female and male ratios for each class were compared across the years 2004 to 2014.

One-tailed t-tests were used to test the null hypothesis that the male ratio was not greater than the female ratio. A standard significance level of 5% was applied to these statistical comparisons, meaning that if a p-value of less than 0.05 (or a $1-p$-value of greater than 0.95) was found, the difference between the average ratios of the two genders could be deemed statistically significant, i.e. that the male ratio was greater than the female ratio. The confidence with which this statement can be made is given by the $1-p$-value.

[17] As denoted by the classes' variances.

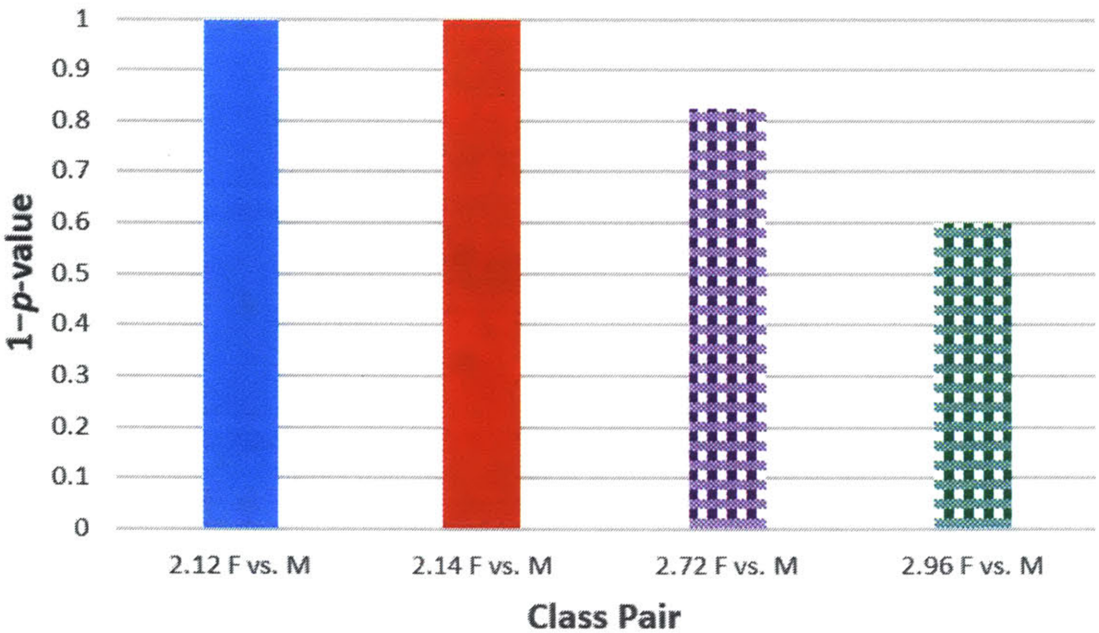

Figure 15: A comparison of the statistical significance of the differences in the female and male ratios of 2.12, 2.14, 2.72, and 2.96. The plaid bars for the 2.72 mechanical design and 2.96 management classes indicate statistically insignificant differences. For the 2.12 robotics and 2.14 controls classes, however, it appears a larger fraction of males in the department take them than females do.

As can be seen in Figure 15, the 2.12 robotics and 2.14 controls classes both had statistically significant differences between their respective female and male ratios, while the 2.72 mechanical design and 2.96 management classes did not.

Thus, it appears a higher fraction of males in the department take 2.12 and 2.14 than females, but this is not necessarily true for 2.72 and 2.96.

An average of 8.1% of males in the department took 2.12 over the years, compared to an average of 5.4% of the females. For 2.14, an average of 5.4% of males in the department took the class over the years, compared to an average of 4.0% of females.

4.3 Comparisons of Class Female Ratios

This subsection takes the step of comparing the classes to each other to see if any notable differences emerge.

Since the classes have been offered for different lengths of time, only data from 2004 (the year 2.12 data were first provided for) and later were used when comparing across these classes.

The female enrollment ratios for each class overlaid on one graph can be seen below:

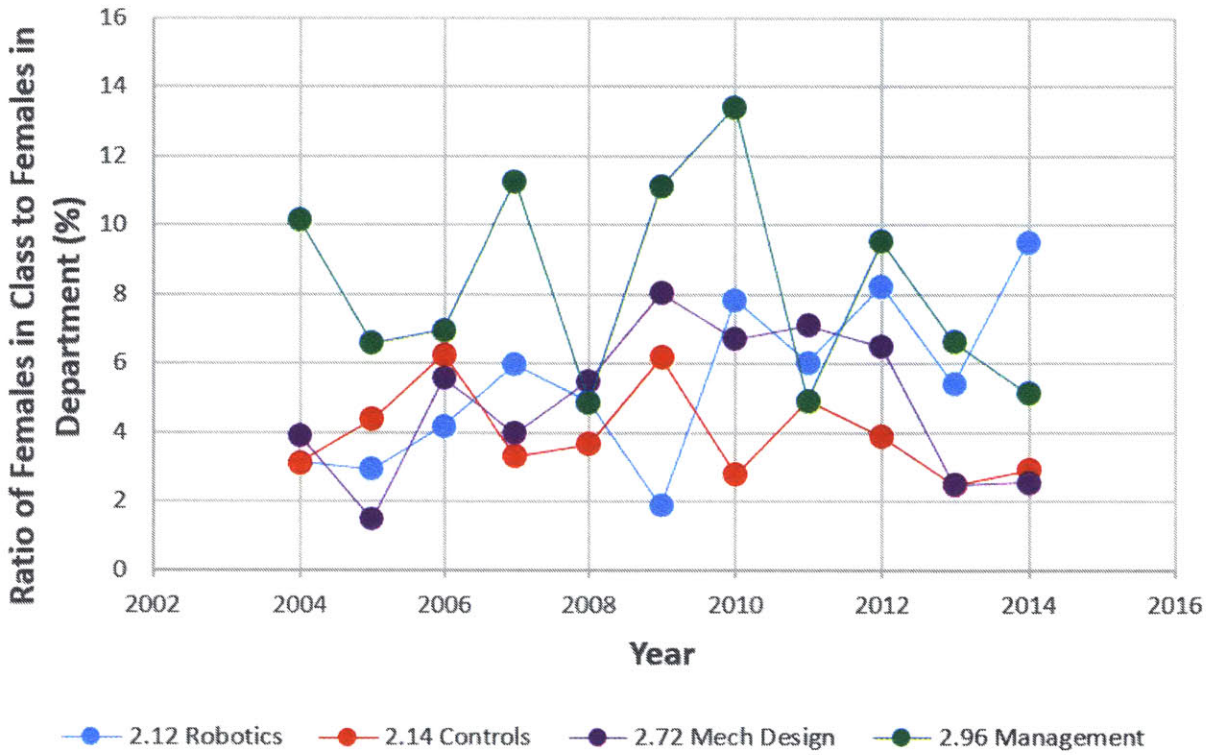

Figure 16: The percentage of undergraduate women in the Mechanical Engineering Department who take 2.12, 2.14, 2.72, and 2.96 over time.

4.3.1 Slope Comparisons

First, it was explored whether the classes' average female enrollment ratios have changed over time in a statistically significant way. To calculate this, the data were plotted in LoggerPro and linear slope fits computed.

Because the sample size is small ($n < 20$), a t-factor was multiplied by the uncertainty given by LoggerPro. If the absolute magnitude of the slope was greater than the uncertainty, then it was determined that some correlation over time existed. If otherwise, no trend was determined.

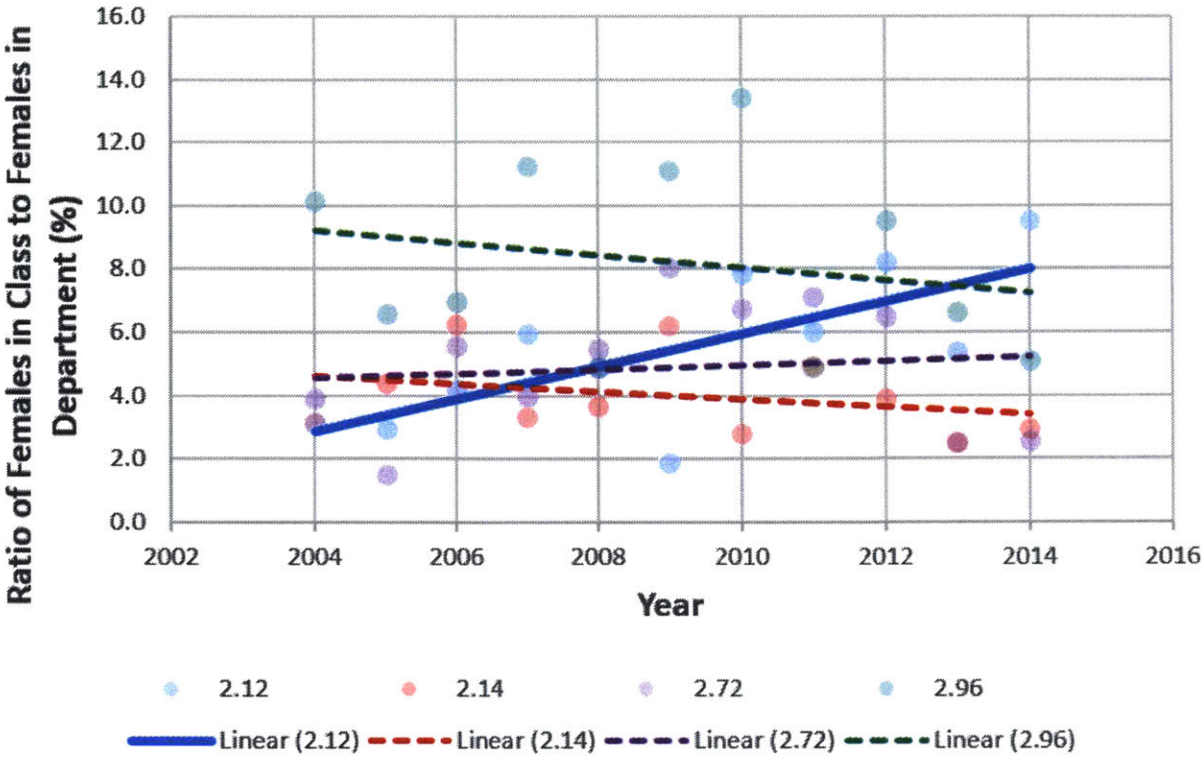

Figure 17: The slopes of the fraction of undergraduate women in the mechanical engineering department who take 2.12, 2.14, 2.72, and 2.96 over time. The dotted slopes indicate statistically insignificant trends; only the 2.12 robotics slope was statistically significant, with a value of 0.54±0.46 year^{-1}. An increasing fraction of women in the department have taken 2.12 over time.

The 2.12 robotics class was the only class that came out with an uncertainty value less than the absolute magnitude of the slope. It appears that there was a slight positive trend over time in which a larger fraction of the undergraduate female population in the mechanical engineering department decided to enroll in the class.

For 2.14, 2.72, and 2.96, it appears that the variations in ratio enrollments between years washed out and no trends could be definitively determined.

4.3.2 Paired T-Test Results for Comparisons of Class Female Ratios

Next, analysis was completed to see whether one class seemed to attract more females from the department than the others. To do this, a paired t-test was conducted between all six possible pairs of classes over the years 2004-2014.

Like before, the paired t-test was used because the two samples were correlated, as the class female ratios were compared across years, and the one-tailed *p*-value calculations given. A standard significance level of 5% was also applied to these statistical comparisons.

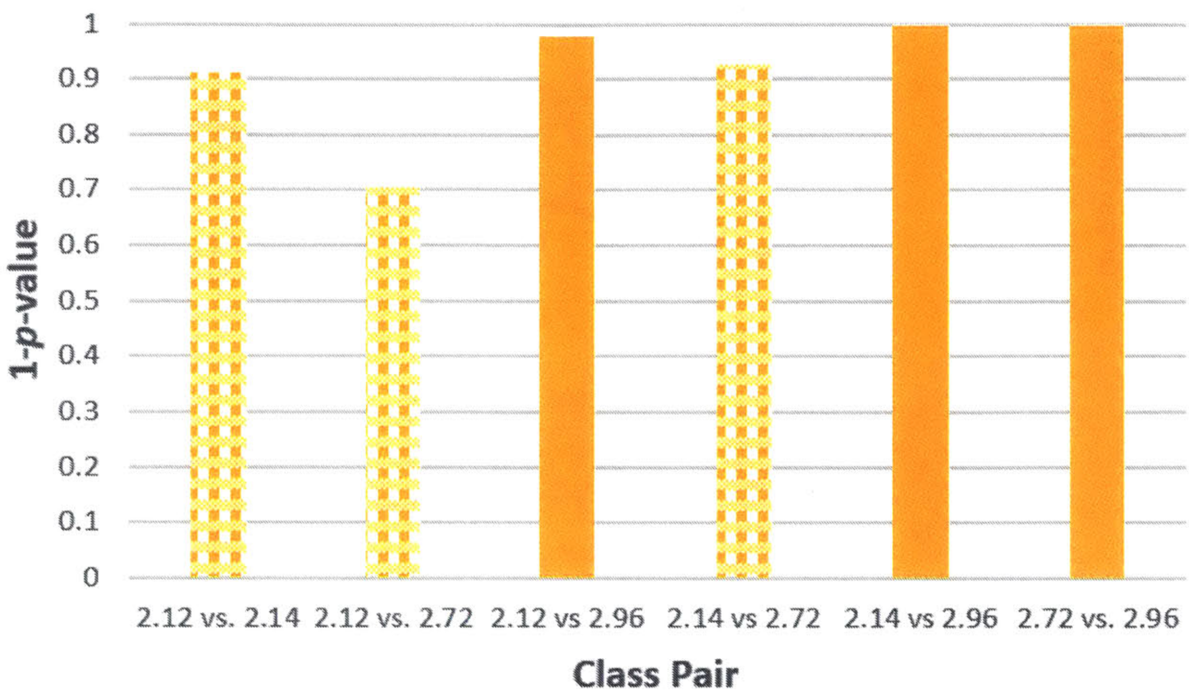

Figure 18: A comparison of the statistical significance of the differences in the female ratios of each possible pair of classes. The plaid bars indicate statistically insignificant differences. Statistically significant differences were found between the 2.96 management class and each of the other elective classes. In other words, it seems that a higher ratio of women have taken 2.96 than 2.12, 2.14, and 2.72.

The t-tests showed that there were statistically significant differences between 2.96 and each of the other classes. In other words, more women seemed to gravitate towards 2.96 than 2.12, 2.14, or 2.72. However, when comparing between 2.12, 2.14, and 2.72, the differences did not turn out to be statistically significant when using a 5% significance level, and so the null hypothesis was accepted for these pairs.

However, another two pairs of classes did come close to the statistically significant difference threshold. With a 10% significance level, 2.12 vs 2.14 and 2.14 vs 2.72 would have differences that are statistically significant.

These results suggest that more undergraduate women are drawn towards the management elective class: is this because they are more interested in leadership or organizational roles and less inclined towards taking more technical-oriented classes? Or could this be because they believe that managerial roles will be more open to them in future workplaces than purely technical roles will be based on past internship experiences or otherwise? These follow-up questions can be investigated in future work.

5. Interview Methods

To better understand how gender dynamics in MIT's Mechanical Engineering Department have changed over the past decade and a half, a range of mechanical engineering faculty and staff were interviewed on their thoughts from their own career paths in engineering to what they have observed at MIT to what they think could be done better in achieving gender balance in the field of mechanical engineering. The goal of the interviews was to understand the context of the MechE Department.

5.1 Participants

Ten MIT faculty and staff were interviewed for this thesis: Anette (Peko) Hosoi, Warren Seering, Mary Boyce, Barbara Hughey, Douglas (Doug) Hart, Betar Gallant, Rohan Abeyaratne, Maria Yang, Stuart (Stu) Schmill, and Brandy Baker. All of them have ties with the Mechanical Engineering Department, whether as faculty, staff, or alumni.

Their current positions, as listed by the Institute, can be found below. If they graduated from MIT, their degrees and degree years are also listed:

Peko Hosoi—Associate Department Head for Education/Professor
Warren Seering—Professor
Mary Boyce SM '84 PhD '87—Ford Professor Emerita[18]
Barbara Hughey PhD '89—Instructor
Doug Hart SM '85—Professor
Betar Gallant SB '08 SM '10 PhD '13—Assistant Professor
Rohan Abeyaratne—Quentin Berg Professor of Mechanics
Maria Yang SB '91—Associate Professor of Mechanical Engineering & Engineering Systems
Stu Schmill SB '86—Dean of Admissions & Interim Director Student Financial Services[19]
Brandy Baker—Mechanical Engineering Undergraduate Academic Administrator

A preliminary list was drawn up based on recommendations from my thesis advisers, Dawn Wendell and Andrea Walsh, with the goal of learning from a representative cross section of those who have demonstrated a vested interest in achieving gender equality in the mechanical engineering department.

[18] Boyce is the only interviewee no longer at MIT; she is now the Dean of Engineering at the Fu Foundation School of Engineering and Applied Science at Columbia University and the Morris A. and Alma Schapiro Professor of Engineering.
[19] After his interview, on April 21, 2016, Schmill was named Dean of Student Financial Services (SFS).

Of course, this list was not an exhaustive list of everyone who cared about making the department (and the field) a more welcoming place for women. The final list was determined based on availability and interviewee referrals. With additional time, I would certainly have liked to interview more people.

The relations between the interviewees can be found below:

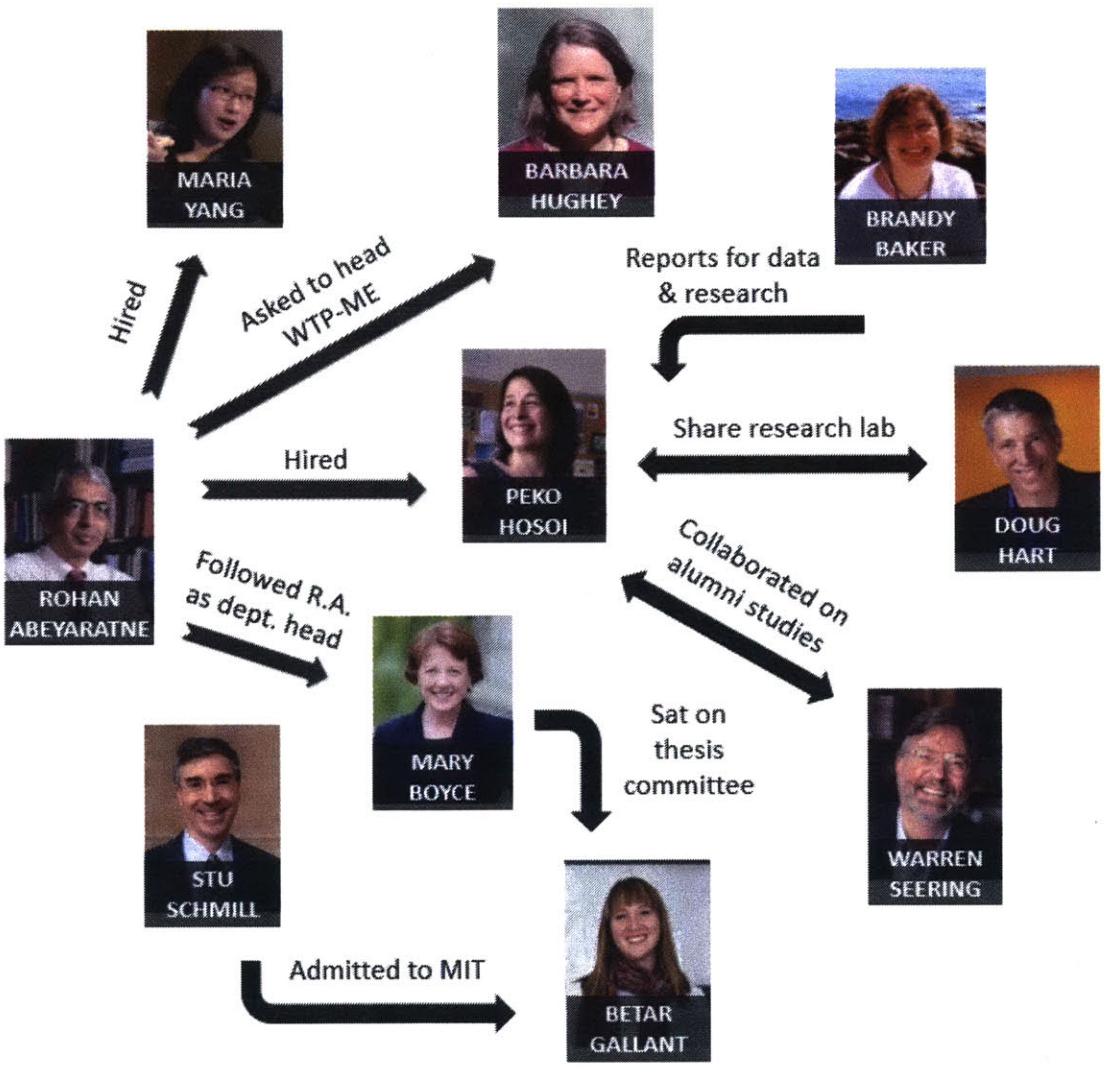

Figure 19: The relations between the interviewees.

In addition, a timeline of when each of the interviewees joined the mechanical engineering department can be seen on the next page (with the exception of Schmill, whose date indicates when he joined the MIT Undergraduate Admissions Office).

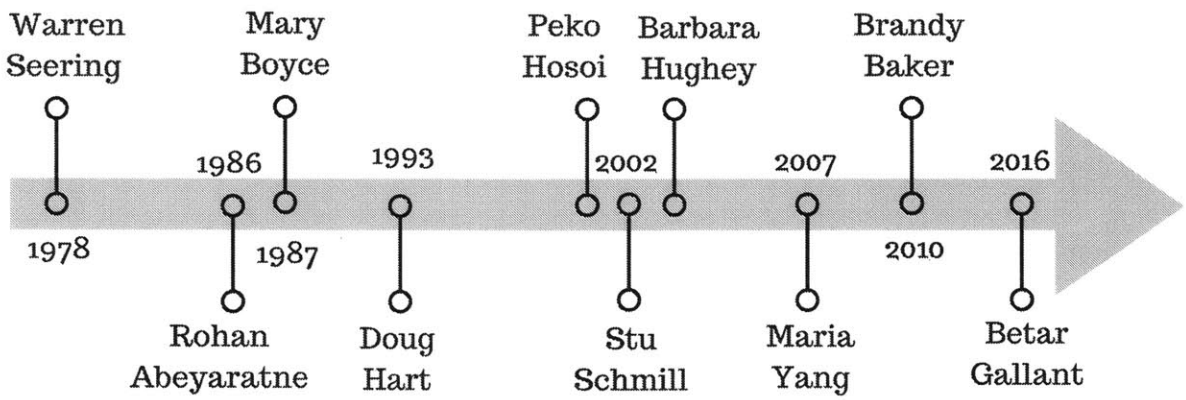

Figure 20: When each interviewee joined the MIT Department of Mechanical Engineering (as faculty or staff), or, in Schmill's case, the MIT Undergraduate Admissions Office.

In addition to the mechanical engineering faculty, Barbara Hughey was interviewed based on her role in launching the Women's Technology Program (WTP) in Mechanical Engineering and for her extensive interaction with students in her role as the 2.671 (Measurement and Instrumentation) Lab Manager.[20]

Stu Schmill, while also a mechanical engineering alumnus, was interviewed due to his role as Dean of Admissions, as his work influences the pool of undergraduate students that the department can itself draw from. Brandy Baker was interviewed as the person in the Mechanical Engineering Department who probably best knows the students overall.

In her own words:

> Half the department has seen me at least once. Probably more. But I just don't remember. Like, you know, if I sign your form for five minutes. [Laughter]
>
> But, you know, I feel like 20% of you guys come in often enough, a couple times a semester or more for some of you… that I feel like by the time you're seniors, I see you enough that… I kind of know you. I know what you're about. I know your personality. I know why you came to the department. I know the kind of thing you're looking to do when you leave.

[20] 2.671 is a required class for every student in the department, including 2, 2A, and 2OE students, so Hughey has seen a large number of students in the department over the years.

> About 10% I know well enough that students have asked me to write letters of recommendation for them. About 10% I know that well.
>
> —Brandy Baker
> Mechanical Engineering Undergraduate Academic Administrator

Each person's interview was conducted in person except for Mary Boyce's interview, which was conducted over Skype as she currently heads Columbia University's Engineering Department in New York City. The interviews were conducted over MIT's January Independent Activities Period (IAP) and early spring semester 2016.

Summary of interviewee choices:
Peko Hosoi—First female mechanical engineering associate department head
Warren Seering—Professor with history of gender research
Mary Boyce—First female mechanical engineering professor with tenure, first female department head in the School of Engineering[21]
Barbara Hughey—Founding director of the Women's Technology Program (WTP) in Mechanical Engineering at MIT
Doug Hart—Recommendation from Hosoi based on his results on the Harvard Gender-Science Implicit Association Test (a positive correlation between women and science)
Betar Gallant—MIT "lifer" (bachelor's, master's, and PhD from MIT), newest female hire to date in January 2016
Rohan Abeyaratne—Former department head, hired Hosoi, Yang, and many other female faculty members
Maria Yang—One of Abeyaratne's last female hires
Stu Schmill—Dean of Admissions, mechanical engineering alumnus
Brandy Baker—Likely the single person who knows mechanical engineering undergradate students best

5.2 Questions

While a core group of questions was asked to most interviewees, the bulk of the interesting responses came from follow-up questions based on what the interviewee first recounted. A core list is reproduced below:

1) How did you get into engineering? (Did your interest start in childhood or did it come later in life?)

[21] The School of Engineering includes the Departments of Mechanical Engineering, Aeronautics and Astronautics, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, and Nuclear Science and Engineering.

2) What encouraged you to apply to teach at MIT?
    a) What was the hiring process like?
3) What were some of the biggest challenges of your career at MIT? What helped you persevere?
4) Some people have said that due to barriers (institutional or psychological, external or internal) that have long discouraged female participation in engineering, there should be extra policies that would be particularly helpful for women trying to go into engineering now. What are your thoughts on the support women should be offered, if any? (e.g. family leave)
    a) In what ways do you think MIT tries to support women in engineering? In what ways do you think the Institute could be doing more?
5) [If former student at MIT] What differences have you noticed, if any, between the MIT then and the MIT now when it comes to the women and men of the Institute?
6) How long have you been teaching?
    a) What differences have you noticed, if any, between the female and male undergraduates in your classes? (e.g. office hour attendance, participation in class, pset completion rates, exam performance)
7) From the students you have taught and mentored, what differences have you noticed, if any, between the career orientations of females and males? (e.g. industry vs. teaching vs. research) (email possibility)
8) Do you belong to any engineering societies? (esp. professional women engineering societies like SWE, NSBE, informal support groups?) (email possibility)
9) What advice would you give to young girls considering going into mechanical engineering? (What are some things you'd want young girls to know?) [wrap-up question]

5.3 Quotes

Interviews were recorded using an iPhone application called "Voice Recorder" and transcribed in Google Docs. Selected quotes were carefully checked before including them in this thesis. In addition, quotes were sent to all interviewees afterwards for approval.[22] Any subsequent edits occurred in the quote contextualization or editorial material (i.e. brackets) rather than in the quotes themselves, with the exception of Hosoi's, Yang's, and Gallant's quotes, which were asked to be directly edited for grammar and clarity. However, whenever possible, the main messages of the quotes were maintained.

[22] At the time of thesis submission, only Mary Boyce had not yet responded.

6. Interviews

This section of the thesis organizes the interview responses into four overarching themes that emerged throughout the interviews: role modeling, faculty hiring, classroom dynamics, and increasing the female representation in the STEM fields. The quotes are first contextualized, and then interspersed with commentary pulled from background research.

6.1 Role Modeling

6.1.1 Paths to Engineering

As discussed in the introduction, how women first enter into the engineering fields is a research topic that has been extensively studied. Last year, for her thesis, MIT Class of 2015 member Kirsten Beatrice Lim drew on existing literature to design a survey for current MIT students to see if the MIT population reflected the trends discovered in previous studies surrounding factors that influence people's decisions to enter engineering.

She found that the male respondents were "more likely to mention a factor that was established at a young age during childhood" (22). An example of a typical response from a male survey participant in Lim's study was that "he had 'a positive experience of building and creating things which I received growing up'" (22).

In her interview, Professor Maria Yang described how her first exposure to engineering came from her family, but she also received encouragement from parents and teachers based on her performance in math and science subjects in school.

> My dad was an engineer. As a little kid, I literally thought he was an engineer on a train. And then when I got older, people kept on saying… "You're good at math and science, so you should be an engineer" but I honestly had no idea what being an engineer meant, other than I wouldn't be a train engineer.
>
> All along, my family encouraged me, "It's a good idea to be an engineer." In my head I had no idea what it was. And I think most people don't know what it is. If you ask, 99% of people would ask, "What's engineering?"
>
> —Maria Yang
> Associate Professor

Echoing Yang's response, Lim's survey showed that the majority of men and women did not feel that they learned what engineering truly entailed until college.

Although she had several industry offers at the time of graduation, Yang said she decided to attend graduate school because she realized did not want to go into industry after all. Later, after she took a break from academia by working for a short while in industry after obtaining her PhD, she said she returned because she realized she liked to manage her work herself.

Like Yang, Professor Betar Gallant mentioned family influences as well as an aptitude in physics that helped spark her interest.

> I really liked physics in high school, but I also really liked writing and reading and all kinds of other things, and I thought for a while that I wanted to go into literature. I had a very positive experience with junior and senior-level physics, however, that made me enjoy it and think that was something I could be interested in.
>
> I also lost my dad to cancer when I was in my sophomore year and he was very technically oriented... He was an engineer and inventor, and while going through that emotional process after he died, I started to look into what his interests were and try to understand why he had chosen that career path for himself. I became more interested in what it meant to be an engineer.
>
> —Betar Gallant
> Assistant Professor

As a child, she stated that she was also not drawn to engineering despite having a strong engineering presence in her family.

> I'm on the graduate admissions committee now, so I see how many people grew up playing with Legos and fixing things. I never did that. It's not that I didn't have an interest. I just was not inclined. I wasn't raised in an environment to take things apart and play with things. I tend to hear that a lot more from guys. I'm just not driven to. That might be a gender thing.
>
> —Betar Gallant

This statement reflects both Lim's results and longstanding results on the gendered divide that begins young for students in STEM.

However, Gallant said she overcame this barrier with an academic approach to mastering STEM courses.

> I approached my career very academically; I set a goal for myself, I saw something that was challenging, and I wanted to work hard for it. It was much more up here [pointed to brain], and less like a hobby interest, but I came full circle because now it's really what I love.
>
> —Betar Gallant

To turn the interest in technical work into a true contender for college major choice, her high school took the important step of providing real-world internship opportunities for its students.

> While I was always interested in technical work, there was a big gulf… I felt like "I've never done that and I don't know how to see myself doing that, and so I don't exactly have confidence that I would know how to approach being an engineer."
>
> But then we had a program in my high school where they synced us up with an industry experience for the summer, and I wound up going to Boston Scientific because their headquarters are in my hometown [Natick]. [Growing up in Massachusetts] was important for me because MIT was a big, intimidating, but inspiring presence.
>
> —Betar Gallant

In some cases, it seems that school influences may even be more than important family influences. A study presented at the American Society for Engineering Education's annual conference in 2014 found that "those [high school seniors] intending to study engineering identified middle and high school instruction as significantly more influential in their choice of major than student proclivity, aptitude, and family influences" (Lichtenstein et al.). The authors surveyed a nationwide sample of teachers and high school seniors.

6.1.2 Instructors

The low female faculty percentage in MIT's engineering departments along with the heavily male-dominated history of the foundation of engineering theorems being taught today means that female engineering students may end up graduating with few, if any, role models. Mentorship and role models have proven to be important in people's career development, but gender can play a role as well.

In his interview, former department head Rohan Abeyaratne gave an anecdote relating the first time the importance of having female faculty as role models truly sunk in.

> One thing I remembered greatly soon after Peko was hired… show[ed] how unaware sometimes people [can be about the importance of mentors]—certainly that I was. When I would walk past the hallway, the number of female students who were going to her office hours or coming in and out or kind of gathering there was striking. And it sort of struck me that, you know, maybe some female students feel much more comfortable talking to female faculty members. And this whole idea around… mentors, you know, like role models—all of that really crystallized with [Peko Hosoi] and Yang Shao-Horn,[23] with those two first hires. Like you could see that these role models were really important.
>
> —Rohan Abeyaratne
> Mechanical Engineering Department Head 2001-2008

As the 2002 "Report of the School of Engineering" stated, "professors naturally want to work with students and colleagues they're comfortable with, and in the traditionally masculine world of engineering, that often means other men with similar backgrounds. Senior male professors tend to take young men under their wings, providing mentorship and access to informal research networks" (Boyce et al.).

In her interview, Professor Peko Hosoi noted that one reason she may have been one of the pioneer female faculty members in the mechanical engineering department was due to her ability to connect with male role models.

> I think the challenges of being a woman in a technical field… are very similar to the challenges of anyone being in a technical field right now... but I have never had a problem finding male role models.
>
> I remember when I was at Harvey Mudd College, they assigned me a mentor. My mentor was someone from the chemistry department and as far as I could tell the only reason they had assigned her to me was because she was a woman. We had nothing in common research-wise… I mean, they should have at least given me someone to me who was a cyclist or something so that we'd have something in common besides gender, right? [Laughter]
>
> —Peko Hosoi
> Mechanical Engineering Associate Department. Head

[23] Rohan Abeyaratne hired six female faculty members during his tenure as department head: Peko Hosoi, Yang Shao-Horn, Carol Livermore, Kim Hamad-Schifferli, Evelyn Wang, and Maria Yang. Hosoi, Shao-Horn, Wang, and Yang are now tenured professors at MIT, while Livermore and Hamad-Schifferli are no longer with MIT.

Furthermore, she brought up the idea that "existence proofs" could be as important as role modeling for female students looking to go into engineering fields.

> When you look at women going into technical fields, and you talk to undergrads, they are not looking necessarily for role models. They are looking for **an existence proof (emphasis mine)**. They want to know, "If I go down this path, is there going to be a job for me?" And if they look up and there are no women, then they think, "There's probably not going to be a place for me here so maybe I should go somewhere else."
>
> In that sense, I think it is important to have women in visible positions everywhere. So that undergrads aren't limiting themselves because they look at the field and think, "Oh, there are no women here. Maybe they just don't take women." Maybe I was very naive as a graduate student in not thinking that, but I could understand how somebody might feel that way.
>
> —Peko Hosoi

While Mary Boyce served as the mechanical engineering department head from 2008 to 2013, she implemented an informal policy of placing a larger percentage of females into the introductory classes teaching positions than males.

> I put people who I felt were the best people in these classes, and I actually had a number of women faculty say, "Am I doing this because they're a woman?" And I said, "No, I'm doing this because you're the best person to be in that class or you know presenting to this group of students." Of course I do understand that... it is a great inspiring element, but please note that it is also because they were the best people for that position.
>
> I do think some of that traces to young women students seeing that, "Boy, there's a lot of fantastic women faculty. That must mean something." I think it's subtle, but presence does send a subtle signal. It has to be **presence with talent (emphasis mine)** and we definitely have that.
>
> —Mary Boyce
> Mechanical Engineering Department Head 2008-2013

6.2 Job Descriptions & Hiring: Broadening the Search

Professional marginalization is insidious, because it so often sounds like complaints about an individual's specific situation.

—Report of the School of Engineering, 2002

As recently as 20 years ago, MIT's mechanical engineering department used to be a much less welcoming place for female faculty members. In the 2002 "Report of the School of Engineering," the authors found that the Institute was "not a hospitable environment for many women faculty."[24] Almost all of the female faculty members in the School of Engineering at the time were interviewed for the report.

Marginalization played a large role in the department's unfriendly reputation at that time. For instance, some of the female faculty members, "despite their superb professional standing and despite the fact that they [were] highly valued by their faculty colleagues, [had] *never* been asked to serve on the PhD committee of even one of their colleagues' students in their own research area" (Boyce et al.) This is important because exclusion from PhD thesis committees can translate into missing out on new research grant ideas when they are discussed.

Some women noted that they had never been "invited to give a presentation at annual departmental retreats" (despite presentations by junior men who had been with the department for less than two years), and lacked representation on influential committees (Boyce et al.). Moreover, some women "were asked to teach lower level undergraduate subjects rather than specialized graduate subjects relating to their own research" and "to change their teaching assignments more often than their male peers," making it more difficult to focus on their research (Boyce et al.).

As the report notes, marginalization compounds over time: "women who are not invited to be on influential departmental committees do not develop the experience needed to move on to higher level administrative positions" (Boyce et al.).

Moreover, percentage-wise, female doctoral candidates in the school received faculty offers only about half of the time that male doctoral candidates did. The authors also discovered that the few female faculty candidates that existed ended up rejecting the school's faculty offers at a far greater rate (40%) than the male faculty candidates did (14%), results that were characterized as

[24] Mary C. Boyce, Penny Chisholm, Edward F. Crawley, Lorna J. Gibson (Chair), Karen K. Gleason, Nancy A. Lynch, and John B. Vander Sande authored the report as members of the Committee on the Status of Women Faculty.

"disturbing" given "MIT's status as one of the premier research universities in engineering in the world" (Boyce et al.).

While a fifth of the male faculty members at MIT reported not having children at the time, almost half of the female faculty members reported the same, with the net effect that "men were subsidized $1,400/year more than women" from MIT's family medical benefits on average and that the "women on the faculty... [were], in effect, subsidizing the families of their male colleagues" (Boyce et al.). The report recommended cafeteria-style benefits package as one that could help close this gap.

Even the gender-blind family leave policy might have widened more gender inequities than it closed. Some women expressed concern that "some men who take the leave use it to further their careers (by traveling the world to give seminars promoting their research or to start companies) rather than to care for the new child" (Boyce et al.).

Several studies have shown the bias women face even getting their foot in the door when they are first hired. A highly cited study published in the *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* by Skidmore Professor Corinne Moss-Racusin and others in 2012 tested this by sending out identical resumes with only a name change (female vs. male name) to over 100 science faculty members from research-intensive universities for a laboratory manager position (Moss-Racusin).[25]

The study found that the fictitious female applicant was consistently rated much less competent and hireable than the corresponding male applicant. Moreover, the male applicant on average was offered more mentorship opportunities and a higher salary ($30,238.10) than the female applicant ($26,507.94). Both female and male faculty members exhibited these biases.

Finally, the 2002 "Report of the School of Engineering" found evidence that female engineering faculty at MIT were compensated less for their work than their male colleagues were: "over half the women full professors received substantial increases in their salary following a request for a salary review in 1995," suggesting that "the need for sudden corrections could be due to the chronic underevaluation of female faculty" (Boyce et al.).[26]

In his interview, Abeyaratne recounted his memories of the state of the mechanical engineering department's female faculty during the time of the report.

[25] Male candidates were called "John" and female candidates "Jennifer."

[26] These salary adjustments, however, still did not account for the full loss of salary due to retirement contribution losses, etc.

> At that time, in the late 1990s, we had one female faculty member in this department... The department had a reputation for being unfriendly to female faculty at the time. In fact, when I became department head, there was a search committee.
>
> When there's a search committee, one of the things they do is they also highlight one of the main items that are of importance to the future of the department in addition to identifying a person… and they identified the lack of female faculty as their number one issue.
>
> [Peko Hosoi] and Yang Shao-Horn were my first hires… During my time, we ended with Evelyn Wang and Maria Yang… and then I stepped down. And then Mary Boyce became department head after that. And it's continued. I think even though we are nowhere near 40%, 50% female faculty, I think the culture is different, you know. We don't think twice about, you know, hiring a female. We still pay attention and try to, you know, find good female faculty. But I think the feeling is different. In those days, you better do it.
>
> —Rohan Abeyaratne

After the 2002 "Report of the School of Engineering" was released, the Dean of Engineering at the time, Thomas Magnanti, decided to immediately take action based on these findings. He "enforced the affirmative action policy more strictly, personally reviewing applications from women candidates and turning back proposals to hire specific candidates from departments that [had] not searched sufficiently for women or given appropriate consideration to women candidates." The Dean also set a target to increase the female faculty percentage in the School of Engineering to 20% by 2010.[27]

Abeyaratne recounted the techniques the department used in recruiting female talent.

> There were two things we did. So one thing was that in those days, we were not that aggressive, [not only in relation to women]… in getting people to apply to MIT, right. We would advertise and we would sit back and wait. And it's like, "We are MIT and of course people would [apply]."
>
> One thing we did was to reach out [to recruit female talent]… Faculty would contact people we knew. We would, you know, ask department heads, like, "Are there strong women graduating? Can we talk to them? Can you encourage them to apply?"

[27] Although this goal was not met, almost 18% of the current engineering faculty is female.

> Basically the way we did it was by increasing the pool of applicants of women. Because the pool, initially there weren't [many] women.
>
> And so the other change we did was not to define jobs that way, but to broaden things. And so we started advertising in mechanics, right. And then you cast a much bigger net, right. So again, the pool of applicants increases… Because once you have applicants, then you don't make any difference in standards. But what we worked hard to do was to get more applicants.
>
> Now it's even more. Now they advertise mechanical engineering. It's like anything. The motivation I think is slightly different there but still, it's a very wide net… Plus, I think the pipeline also is getting larger. There [are] more women getting PhDs and wanting to go into academia.
>
> —Rohan Abeyaratne

As one of the most recent hires (January 2016) by the department, Gallant has experienced these changes firsthand.

> I went to Caltech for my postdoc, and I applied to come back here right away in the fall that I arrived there. There were a couple of positions open at MIT. I applied to all of them. And then there was one position open at Caltech for a physics person, which I didn't fit, but I applied for that too. So I got an interview here.
>
> When I applied, I think there were four positions available. Three were in specific focus areas. One was in thermal sciences, which was broadly what I would fit into. It didn't say, "We want someone working on engines or we want someone doing something very specific." It just said "energy" and keywords that I could fall under. And then there was also a general search.
>
> —Betar Gallant

The current faculty position opening on the School of Science Faculty Search site lists the following ("Faculty Positions in Mechanical Engineering":

"Candidates in all areas related to Mechanical Engineering will be considered, including, but not limited to: (1) mechanics: modeling, experimentation and computation, (2) design, manufacturing, and product development, (3) control, instrumentation, and robotics, (4) energy science and engineering, (5) ocean science and engineering, (6) bioengineering, and (7) micro/nanoengineering. Our department is committed to **fostering interdisciplinary research (emphasis mine)** that can address grand challenges facing our society."

In addition, the last lines indicate that "MIT is an equal-opportunity/affirmative action employer" and that "women and underrepresented minorities are especially encouraged to apply." Of the engineering departments, only the department of electrical engineering and computer science did not add a line especially encouraging minorities and women to apply.

Contrasting Gallant's hiring experience with Hosoi's hiring experience, we can see the large changes that have been made over the past decade:

> So I answered the phone and the guy on the other side says, "Hi, this is Rohan Abeyaratne calling from the Department of Mechanical Engineering at MIT." And I thought, "That's nice." And he said, "As you might know, we have a search going on." And I thought, "Well, I knew you had one going on two years ago when I applied." And then I thought, "Maybe he's going to ask me to send an updated CV or something." And instead he says, "We'd like to make you an offer." I was like, "What??" There was no job interview. There was no chalk talk.
>
> When I got here, there were a lot of women who had been hired at the same time. And at a junior women faculty lunch we started talking about it. "Oh, how did you end up at MIT?" "Well, somebody called and asked me to apply or asked me to come." "Somebody called and asked me to…" Every single person in that room… All of us already had jobs. None of us would have applied to MIT if somebody hadn't called us… or taken the time… and just said, "Come on over." I think that completely changed the landscape.
>
> And it wasn't just Rohan. It was across departments. People were calling women who were already in established positions (I was an assistant professor, it's not that established, but I had a faculty position), and saying, "Come talk to us."
>
> Let's be honest; I don't know what happened when I got hired, but I probably would not have been hired at MIT without a targeted hiring practice. And let me also clarify; this is in no way a reflection of the imposter syndrome. I don't feel that I shouldn't be here. [Laughter] But I feel that to get somewhere like MIT, you have to get lucky (regardless of your gender). And there are so few women in the hiring pool now that if you're going to rely on getting lucky to find good women, it's going to take a long time.
>
> —Peko Hosoi

Hosoi's mention of the imposter syndrome refers to the "internal experience of intellectual phoniness that appears to be particularly prevalent and intense among a select sample of high achieving women," as defined by psychologists Pauline Rose Clance and Suzanne Imes in the first paper published on the subject in 1978 (Clance).

> We need to understand what makes a great woman apply to one of our positions... for example, when they hired me and when they hired all of those other women, none of us would have applied. Zero. Out of a room full of women zero would have applied. And that was because when we read the job announcement, we thought "That doesn't sound like me." So there needs to be a way to write those job announcements in a way that women will read them and think, "I should apply."
>
> We're moving in that direction with a broad search. But yeah, even I—I had been a postdoc at MIT so I know and love MIT—and I still didn't read that job announcement and think, "Oh, that sounds like me."
>
> —Peko Hosoi

Hosoi then went on to relate an anecdote by a friend who starts companies:

> I heard from a friend who has learned [from] hiring for his companies… that if you ask a woman, "Do you know Python?" and she doesn't know Python but feels confident she can learn Python, she will say, "No I don't know Python, but I'm confident I can learn it." If you ask a man, "Do you know Python?" and he doesn't know Python but he's confident he can learn Python, he'll just say, "Yes." [Laughter] I think there are subtle gender differences like that.
>
> —Peko Hosoi

Issues like the confidence gap and the culture of perfectionism that have seemed to disproportionately affect women have been extensively studied, and have even begun to permeate mainstream culture. Facebook Chief Operating Officer Sheryl Sandberg's 2013 book, *Lean In: Women, Work, and the Will to Lead,* spent 12 weeks atop the *New York Times* nonfiction best-seller list. The memoir urged women to step up and be prepared to take risks and to take on more responsibility in their careers. As Sandberg wrote in her memoir, "We [women] hold ourselves back in ways both big and small, by lacking self-confidence, by not raising our hands and by pulling back when we should be leaning in" (8).

Like Abeyaratne, Professor Doug Hart was also involved with hiring in the mechanical engineering department at the time that these changes in the faculty search process took place.

> There was a mandate that we had to give special consideration to any women applicants which means that we could turn them down, but we had to justify why we turned them

> down. Normally, we don't have to justify everything. In this case, well, if you got a minority… you have to do all this extra paperwork. So they were subtly forcing it, the issue, right. It was a mandate from the Dean of Engineering.
>
> It was a policy change with the attempt to try to balance the enrollment. And they said… "If you get a good minority or women candidate that doesn't fit your search, yes, you can turn them down, but you should pass that person on to other searches within the university so they can look at them too."
>
> The idea is… good candidates are hard to find. If you find a good candidate, you should at least let other people try to find it. And that should probably go for everything, but they mandated it for women and minorities.
>
> —Doug Hart

However, not everyone was on board at the time. Hart cited one male faculty member who resisted this policy change because he did not think it truly reflected the values of a meritocracy.

> [He] strongly felt that, you know, every time you have a search, it's a meritocracy. You should go and find all the candidates, male or female, and select the best candidate.
>
> You know, it's easy to say that but he's taking the role as an individual selecting somebody for this position. And you could argue that his viewpoint is right but from a higher level, the viewpoint is that, "We're a team. We're a university. We're a school." We should have a balanced [school]. And that's part of the equation also. And I think the global view won out for the good.
>
> Now that I've seen teams and startup companies work and teams working in my class and so forth, I believe that the group dynamics is probably as much or more important than any individual. It's nice to have superstars. Superstars don't always make for a good team. It's better to say, "Okay, I want superstars, but I want them to be able to work together."
>
> —Doug Hart

Institutions have long been grappling with the meaning of a meritocracy: when there has been a history of sexism and underrepresentation of women in the field, what should a meritocracy look like? MIT, and many other higher education institutions, answer with affirmative action policies in both its student admissions and faculty searches.

In addition, Hart mentioned differences between the ways the department could try to attract more women.

> I was partly on this [search] committee partly because of my wife again.[28] They [felt], "Oh, well Doug must not be biased," or something like this. And um, I had a huge falling out with Mary [Boyce] on this issue. It was the same time that the women's report came out. The issue was this. I felt… why not say that our group or our department is unhealthy, that we need to balance the genders better?
>
> My feeling was that we should just admit that we have a problem, and then we should then go out and look for extremely competent women to try to balance it better. Because if we could reach a certain level of percentage of women, then my idea is that other women could look at it and say, "Oh, I belong here." The problem was if it's all guys, they don't feel like they belong.
>
> And so it wasn't correcting itself. And it needed something drastic. And Mary's problem was that if we did that, she felt that all the guys would feel the women were subpar, that we hired them only because they were women.
>
> —Doug Hart

In fact, in a follow-up report published in 2011, titled "A Report on the Status of Women Faculty in the Schools of Science and Engineering at MIT," the authors mentioned female faculty concerns that the new faculty search procedures, which aimed to remove biases in the search process "can lead to the perception that women faculty are unfairly hired, and later, to the incorrect perception that that standards of hiring and promotion are lower for women faculty" (Chisholm et al. 5). These misperceptions can decrease the confidence of women faculty and contribute to the feelings of imposter syndrome.

However, Hart still believed that it is more important to keep the faculty search broad.

> We just open up the search and that gives us a bigger pool of people and so the people we do bring in would be extremely competent. Mary didn't feel that way at all. So yeah, it went back and forth. I just felt like we should address it head-on. We should say that we're wrong and that we're biased and that we've developed this unhealthy department and we need to correct this.

[28] Hart's wife, Anne Hart, is a Professor of Neuroscience at Brown University.

I guess I still feel that way. I still feel that… a team of people is more than its individuals… If the goal is to develop the best department in the world, that's essentially a team, and you need to take into account the fact that gender's part of that that you need to correct and represent everybody because our student body is very diverse in turn.

I think it's a lot healthier now, partly because we have people like Peko, who's very outspoken and you don't push her around, right. And she's well-loved and respected too.

I think Mary Boyce was the generation before Peko and very well-respected and very strong-willed. And certainly she's, like Peko, helped change things. So I think you need mentorship, you know.

I don't think that every successful woman in our department should have to be as strong, you know, and independent as Peko just to be successful… There should be a variety.

But I will say that those strong-willed mentors help push people's views… Also I think in general, engineering has become more healthful, more balanced. And so the incoming faculty have more of a balanced perspective. Hopefully, some day, it won't even be an issue and we won't think about it and we won't even talk about it.

—Doug Hart

6.3 Classroom Dynamics

Not everyone comes into MIT with the same background. The undergraduate admissions office carefully chooses the admitted classes with the aim of diversifying its undergraduate student body. In this section, we explore what this means in the major and the classroom when people from different backgrounds come together, with a gendered focus. Recruitment and admission policies will be further discussed in Section 6.4.

6.3.1 Undergraduate Student Experience in the Mechanical Engineering Department

Brandy Baker, affectionately referred to as "Brandy" by the students, is well-known in the department as the go-to person mechanical engineering undergraduates seek out if they need help. This help ranges from merely signing a form to providing life advice to struggling students based on years of counseling MIT students.

Of those students she sees who are struggling, Baker noted differences in the way that the women and men dealt with stress.

> Young men hardly ever cry. Young women will shut the door and cry. They don't want to walk out crying, but they're perfectly happy to cry in private and let the stress go, you know what I mean. There are some young men that do that but it's maybe half as many as the young women. And there are certainly some young women who won't. But they're much more rare.
>
> I can't tell you how many times I see the young man in my office who's not doing well in class, fighting back tears or trying to act like he's not ready to cry. You know, and I'm just like, "Just let it out, it's okay, like I'm not going to judge you." So I think there's still a cultural difference in stress and that might go into the asking for help culture also.
>
> Out of the students that hide, it's a little bit more likely that they be young men, but we also have female students that hide, you know, that do the, "I'm in trouble. I'm behind. I'm behind in every class, so I'm going to stop talking to people and hide in my dorm room."
>
> But it does tend to be more young men who go to the extreme. You know what I mean? In the middle, I think it's about even, but I've had more young men have to have [MIT] Housing [administrators] go walk them to me so that they will speak to a person than young women, although I've had to do it with young women also.
>
> —Brandy Baker

On the other end of the spectrum are the students who excel within the department—these students who are not only able to maintain perfect GPAs, but also go above and beyond the class requirements of the major. According to Baker, when she first came in as the department's academic administrator in 2010, women tended to not only outperform men at the very top, but also on average. The latter trend would reflect the trend at MIT as a whole, in which the female students tend to have slightly higher GPAs than the male students (Chin and Tekiela).

> When I started... definitely women tended to have slightly higher GPAs than the guys. If you averaged the GPA for all the women in the department, the 40% vs the 60% guys, the average GPA for the women would be higher than that for the guys. I don't know if that's still true. This is when I started in 2010 and certainly also in 2011.
>
> Because in 2011 is when I noticed the trend and I was like, "Why do we have so many 5.0s that are women?" I think it may be equalizing now. I think maybe five years ago women came into MechE for different reasons than they do now.
>
> —Brandy Baker

Hart corroborated Baker's observations with his own account of when he handled the MechE Student Awards one year:

> Out of the 5.0s that were getting awards [for Outstanding Academic Achievement], I think seven of the ten were women. And people said, "Oh, yeah, but they're taking 2A, and they're taking easy classes." I heard this. I swear to God, I heard this.
>
> You know and I thought about it, and I thought, "Ah, no. I don't believe that. I know these women. I don't believe it." So I went back and I looked at their records. They had actually taken the hardest classes there were, you know. And it was just so wrong, you know, that comment. They aced all the really hard classes. And they took more classes than the average people. So I just…
>
> Then I realized, you know, "Come on." But then you say, "Okay, so that's not the truth. The truth is that they really are deserving and they are better." But we have, what, oh, I don't know, 40% women or something… and yet our seven out of our top ten students were women. And I went back and checked and no, indeed, they deserved that award. So then you say, "Wait a minute." Why should there be a bias at all? Because the women were winning all of the awards.
>
> —Doug Hart

This unequal perception of male and female success is a pernicious form of sexism that may chronically undervalue the professional achievement of women, which in turn may prove especially harmful when the women may have faced larger barriers to reach there in the first place.

Five years ago in 2010, a little more than a third of the undergraduate mechanical engineering majors were female (36.5%). Compare this to 2015, when almost half (46.4%) identify as female.

Baker hypothesized that this large difference in the departmental gender makeup over the years may have affected the type of woman who joined the department then and now.

> I think the perception now is that we're pretty much even women and guys, and so I don't think women feel intimidated coming into the department now. I think in 2010, that might have been different, that it still might have been viewed as more of a male field, and so the women that came in were like, "I'm going to be a mechanical engineer. And I'm going to be a good one. And I'm going to show them."

> So it was a little bit less of a, you know, "mechanical engineering is fun" and more of a "I'm going to prove I'm as good as the guys" mindset… as opposed to some of the guys who enter the department because like their friends are in the department or their parents pushed them in the department.
>
> That was less common with women in 2010, and might be more common with the women now. That's all hypothetical. I have no evidence to support it. That's my theory, though.
>
> Like you know in 2010 and 2011… the high end on the high achievers... was women-centric. But I think that gap is closing… as more women are coming in to MechE without necessarily having to feel super confident about it, you know what I mean? I think in 2010, to be MechE instead of one of the other departments, you have to feel like you were a good engineer coming in.
>
> Now, I feel women feel more able to explore the major without feeling confident they're going to do well ahead of time. So I think… you can get female students that have maybe never even did FIRST Robotics or built a thing in their lives trying it out.[29] You know what I mean? And I think that maybe wasn't as true in 2010. Although you probably have to interview some alums from 2010 to know for sure.
>
> —Brandy Baker

Some education researchers have attributed adding flexibility to an engineering degree to be an effective lure for drawing women in who might not otherwise have chosen a technical major.

The Status of Undergraduate Women at MIT report also cited the flexible degrees in mechanical engineering and physics as potential reasons that the female enrollment grew within their respective departments: "The additions of 8-Flexible and 2-A suggest that flexible majors attract women to traditionally male-dominated fields" (Chin and Tekiela 12).

However, while 2-A did attract women to the mechanical engineering department, it also attracted men in roughly equal numbers. Thus, the perception that women disproportionately flocked to the flexible degree, at least in the mechanical engineering department, does not seem to be true.

In addition, Baker disputes the perception that 2A offers an easier route than standard 2 does.

[29] FIRST Robotics is an international high school robotics competition.

> The top 5% of overachievers are the top 5% of overachievers, and that's true for 2[30] and 2A. They all have like 300 units... They've just done way more than a typical student is able to time manage. I think that 2A is very like 2 with those distributions. It's just that the flexibility allows it to become exaggerated, perhaps more than the Course 2 degree. Because there's very little flexibility in the Course 2 degree and the flexibility [in 2A] lets you maybe take one or two more easy classes if you're taking an easy path, or five or six or ten more hard classes if you're taking a hard path, you know what I mean?
>
> Course 2A is, like everything at MIT... a choice. And Course 2A just allows you much more freedom in those choices, so you can make it as hard or easy as you want and there's a bit more flexibility in the middle ground.
>
> But that's a 2 vs. 2A thing. That's not really gender-specific. I think that fed into the gender arguments when 2A was more heavily women than men. But I don't think you can say that now anyway, even if you were to say that 2A is easier. But I don't really feel 2A is easier. I mean, it has some potential to be perhaps easier, but it has the potential to be harder too, right... You take things out of the MechE comfort zone. Certainly premeds. Nobody who's premed could say that their 2A is easier. [Laughter]
>
> —Brandy Baker

However, Baker said that one factor she considered when trying to explain the large jump in female enrollment from 2009 to 2012 was the visible female leadership in the department.

> We hypothesized that when we went from about the 40 to 46 percent, when we took the little five or six percent jump up, we hypothesized that it might have something to do with having a female department head. Mary Boyce was department head at the time. But she didn't really interact with the undergrads much. She didn't go to student events and stuff. It was still John Lienhard, who's a guy. So it's sort of like, "Well maybe, but I'm not sure..." Like I wasn't super confident that you guys know who the department head is. [Laughter] And I'm not sure that impacts your decision to choose a major.
>
> So it could be that, you know, we promoted a woman, so it makes it look like we have maybe a better population of women in the leadership in the department... You know, I mean, for the amount of women faculty that we have, we have pretty good leadership in the department that are women.

[30] When Brandy refers to "2" or "Course 2" in her interview, she is referring to the standard 2 track and not the department as a whole.

> But we're not really. I mean, we're not 46% women faculty, that's for sure. [Laughter] I don't know. Maybe we're doing better than the other departments.
>
> —Brandy Baker

Boyce was the first female department head in MIT's School of Engineering (SOE), although women had served as associate department heads before ("Boyce to Head MIT MechE"). Currently, there is only one female department head in the SOE, Paula Hammond, who is also the first female department head of the chemical engineering department ("Department Heads").

Baker also hypothesized that word of mouth may have played a large role:

> I just have no idea why [so many women joined]. Other than we had happy women students, and happy women students told their female friends that Course 2 was a happy place to be. And so gradually over time more and more women joined.
>
> I think that's the most likely scenario because that seems to be how things work in the undergraduate world.
>
> MechE is, "Come to MechE, 'cause we have fun!" That's the selling point for students. Every student that's been referred and been told, "Oh you're unhappy with your major? You should join Course 2!" says their peers are all like, "And they're in 2.007, they're having fun, or they're in 2.001, and they say it's great." Or they're in whatever class. You guys brag about your classes. Course 6 brags about being able to get a job after suffering for four years. I mean, which is the better draw? For women, right? Maybe women have prioritized personal happiness over employability. Not that you're not employable. I mean, you're totally employable.
>
> I think that, you know, for MechE, you guys are happy while you're here. You're not just happy that in the future you will be happy. Like it's not like, "And I just have to get through MIT to be happy." It's like you're happy while you're here so you draw in other students by being happy with the stuff you're doing right now, but particularly sophomores. So kids get super excited about 2.007. Even in the bad years when it's like way too much work. [Laughter]
>
> —Brandy Baker

6.3.2 Group Work and Gender Balance

MIT's core mechanical engineering curriculum requires students to take several group classes, with emphases on teamwork, design, and manufacturing, such as 2.007 (Design and

Manufacturing I), 2.008 (Design and Manufacturing II), and 2.009 (Product Engineering Processes). In addition, elective classes offer further group work opportunities.

In Yang's 2.00 (Introduction to Design) course, the instructors split the predominantly sophomore class into small groups of three to five to work on two projects throughout the half-term. In her interview, Yang said that the course staff take care to balance groups by gender.

> We do, actually, [try to balance the groups]. When I was in grad school, I remember my professors, with the best of intentions, would say: "Well, there aren't that many women in class so we'll split them up so that there's one woman on each team." I didn't like that because you'd end up being the only woman, and sometimes that would mean a group dynamic where your voice wasn't always heard. So we always try to make sure [women are not alone on a team].
>
> This is a something I'm wary of: students who have a lot of experience building beforehand are somewhat at an advantage. They feel very comfortable in project classes. Sometimes, women don't get as much experience early on doing this. Personally, I had lots of experience making things, but not with machine shop tools. So I think it's not because of inherent abilities, but it's because they didn't get the experiences growing [up].
>
> —Maria Yang

Hart, who has taught the 2.013/2.014 (Engineering Systems Design) sequence for half a decade, described his observations of gender dynamics in group work settings:

> I've never had this happen before, but we had three groups running this year. And in two of the groups, the women complained that they felt their input was being suppressed by the group. And I asked. I've never had this before, so this came as a shock. I asked a lot of people, you know, what was going on, what happened, including Peko, and Peko's reaction is that her husband also encountered this at Lincoln[31] and it seems to be something… people are more aware of at this point. I don't know that anything's ever different. I think that maybe what's different is that the women involved were extremely strong-willed, extremely competent, and… minorities in this group.
>
> In the past, my classes have been much better balanced... I personally think a well-balanced group is so much more productive and much healthier... I've always felt

[31] According to its website, MIT's Lincoln Laboratory is a "federally funded research and development center chartered to apply advanced technology to problems of national security."

> that when you get a bunch of guys together, it's like *Lord of the Flies*. [Laughter] I mean, you know, maybe it happens with women. I don't see it because as soon as I show up, they change the talk.
>
> I think in my class, it was deeper than that. I think some of the women felt that the guys were actually discrediting their input. None of them accused them of being active. But I think that passive is actually worse because it's hard to deal with.
>
> —Doug Hart

Hart pointed to the media as one reason gender imbalances might occur:

> We have a handful of women faculty members and it's growing, but society hasn't caught up, right. We're the cutting-edge because, you know, we're more of a meritocracy. But I think if you look at, you know, the older generation, that hasn't caught up yet. And then as a result… these guys are developing stereotypical images from when they're kids and through television and everything else, and then they get to school.
>
> When they see the groups are equal, they forget each other are, you know, girls [and] guys. They work beautifully together… It impresses me tremendously.
>
> But what I was shocked at this year was that when you get this imbalance, they revert back apparently.
>
> And to be honest… I find I have biases because I found that strong women make better CEOs than the guys do. And so maybe I have a reverse bias, I don't know. So maybe that's one of the things that happened. And part of that might have come about because I had a string of very strong women CEOs that were very successful, and then I had a couple of weak guys that weren't successful. And so maybe I developed a bias.
>
> —Doug Hart

Currently, women hold only 4% of the CEO positions at the S&P (Standard & Poor's) 500 companies ("Women CEOs").

> In the past years what happens is if I hire a woman as the CEO, I don't see any bias towards organizing the structure of the class as dominated by women or men or anything else, so this one surprised me. It happened partly I think because instead of one project, we went to three projects and I wasn't involved as much.

> One of them was a car project. More of the guys migrated towards that for whatever reason. One of them was an underwater vehicle. More of the women migrated to that. And then one of them was a soldier nanopack. More of the guys migrated to that. Apparently guys like things that drive and blow up. [Laughter] I personally like the underwater stuff.
>
> —Doug Hart

2OE has actually been fairly gender balanced over the past decade and a half, although the number of students in the major is very small (fewer than 20 total each year). The female percentage in the degree program has ranged between 40 and 60% most of the times over the past decade and a half.

To investigate, Hart decided to reach out to past years' students to ask for their opinions.

> Many of them said, "What's the complaint about? This is life for us. You just have to get used to it." My wife was like that... Her attitude was equally surprising to me because she said, "Yeah, yeah, we hear, you know, ridiculous things all the time. Yeah, it's prejudiced as hell, but, you know, that's just the way life is. You just got to get thick skin and live with it. Just ignore it."
>
> The TA's female,[32] which makes a difference because I asked her what was wrong and she's kind of the opinion of, "Well, you got yourself in the trouble because you asked the question which means you're going to hear the answer."
>
> I got a note from this former student's mother… She just unloaded on me… how evil guys are and how her whole life she's been a computer scientist and her ideas have been put down.
>
> And I thought, "Oh my God. I'm this evil person. I don't know. What do I do?" And then my TA said, "Well, what do you expect? You opened the door, you know. **Of course you're going to hear the complaints. You're the guy that's listening" (emphasis mine).** But I felt… overwhelmed at that point. I sympathized, but I can't fix it. Let me try my students. I'll work on them. I can't fix your life; I can do mine.
>
> My own opinion is that there are certain faculty who are not open to even hearing about it, right. They just shut it down. They don't want to deal with it. Or maybe they're prejudiced in themselves, right. And so they don't see it as a problem. They just say, "Oh,

[32] TA stands for teaching assistant, usually a student who helps the instructor lead recitations, grade exams, hold office hours, or any other instructional tasks.

> you're whining." And **that's the answer to any problem you don't want to deal with: "oh, I got a whiner student" (emphasis mine).**
>
> —Doug Hart

Hart, as one of the male participants in the gender equality movement, follows a long line of male faculty members at MIT who cared and, most importantly, listened and acted upon disparities; this list includes former MIT President Charles "Chuck" Vest, former Dean of Science Robert J. Birgeneau, former mechanical engineering department head Rohan Abeyaratne, and more.

> Two complaints from separate groups, both of them were very good, outstanding students whom I have great respect for: that's not a small problem in my [book]. To me, something's wrong. So I felt very obligated to fix it. I just don't know how. I would love advice on this. You know, to be honest, it would be so great if there was somebody I could go to and ask, you know, "How do you handle a situation like this?"
>
> And actually when you point out, you say, "Well, was it this person?" They say, "No." "Was it this person?" "No." They say, "Well, no, it wasn't an individual."
>
> You know, when you confront the [individuals], they're always very polite and careful and so forth. And they said, "It's really the collective group that is the problem." It's the mentality that then overrides everything. But individually, everybody is very supportive and helpful, so any one-on-one, there's no problem. Ever. It's as a group, they felt that their ideas weren't taken into consideration.
>
> I can see that. Like I said, it's like *Lord of the Flies*. Each individual is a perfectly nice person. You get them together, something happens. But you know, the funny thing is when you do things like grad students in a lab, when you get the right combination of people together, magical things happen. They seem to be able to perform far better than each individual can separately.
>
> How do you tell a group of very conscientious, very good group of guys that, "Hey, you're ignoring this woman over here who's brilliant and she's got great ideas, and you're running over the top of her because you're all chest-thumpers with full testosterone and, you know, she's quietly over there, you know, feeling like an outcast and you guys should be pulling her in because she's smarter than you are," which, by the way, was the case in this case. [Laughter]
>
> —Doug Hart

6.3.3 Speaking Up in Class

It has been well-established that the way students participate in American college classrooms is gendered. In a 1985 study at Harvard College, former director of the Harvard-Danforth Center Catherine Krupnick found that male students spoke two and a half times longer when they were in classrooms that had a male instructor and were in a male-majority class, a setting that occurs frequently in STEM subjects. Her data suggested "that a teacher's gender can play a role in classroom discussion, in the sense that it appears to influence the extent to which male students dominate classrooms" (Krupnick).

Moreover, she found that "there were considerably more one-time contributors among women than men" as women would sometimes stop participating once they were interrupted in their first answer (which occurred much more frequently to women than men) (Krupnick).

Two interviewees brought up the idea that class size may affect participation in a gendered way as well. Abeyaratne discussed his observations from teaching 2.001 (the introductory mechanics class) this past term:

> It's interesting now that I think about it. So in recitation, I would say there were more questions from women. In lecture, there were probably less questions from women. I think. I mean, I certainly can think of some women who used to ask questions. It's not that they didn't ask questions, but relatively I think it was less. But definitely in recitations, it was more. So maybe it's just class size. The setting.
>
> —Rohan Abeyaratne

Boyce echoed Abeyaratne's comments on the importance of setting differences when she taught at MIT (e.g. labs vs. recitations vs. lectures).

> I do think creating learning environments that have a multitude of ways of interaction are important for women but I think obviously also for men. It helps create the dynamic and the comfort to ask questions, to gain more confidence, and I think that's important for everyone.
>
> —Mary Boyce

Gallant, who was the most recent interviewee to go through an MIT education, described her experiences in the classroom as one that reflected the current body of research surrounding female participation in lectures:

> It took time for me to get confidence in myself. I did feel like some male students felt more comfortable speaking out and asking questions. They look like better students when they do that.
>
> My strength was not my participation in class, or my ability to engage the professor, or demonstrate in real time what I knew. My strength was that I would go home, and I would read the book. I would do the problems really painstakingly. It was much more academic than just a kind of "gut feeling." It took time to build intuition. I really worked at it, and then I did well in my classes. I have to say, when I look at the other successful students from my year, a number of the female students I knew were like that.
>
> I don't remember as many female students coming in with full confidence and saying, "Professor, you didn't solve this problem right. Don't you mean to do this? Or are you leaving this out?"[33]
>
> We were very studious. Perhaps our approach was different. I don't know if that's because we started out with a lower level of comfort than some of the guys in the class. But I do remember thinking about that a lot. That discrepancy was certainly apparent to me, not in all cases, but enough to be noticeable.
>
> —Betar Gallant

However, her shyness in the classroom did not translate into her pset groups (a presumably smaller setting), which were composed almost entirely of male students except for her.

> Yup, they were all-male, actually, if I remember correctly. They were often coming to me to discuss, because I always started the homework earlier than the others. [Laughter] Even though they were more outgoing in class and everything.
>
> —Betar Gallant

6.4 Increasing Female Representation in STEM

This subsection takes a look at how the admissions and media culture has affected MIT's female STEM representation, and what advice and recommendations the interviewees would give.

[33] In a follow-up exchange, Gallant, who is co-teaching 2.005 (Thermal-Fluids Engineering I) in the Spring 2016 term, noted, "Interestingly, this seems to have changed a bit. I notice a lot of female students being much more outspoken in my 2.005 class! Perhaps the times have changed, or maybe my year was just my year."

6.4.1 Admissions

Before MIT students can choose their majors, they must first go through MIT's admissions process and be admitted. How and why the office makes the decisions it does when it comes to minority admissions is important because that affects the pool of available minorities. Through an interview with MIT's Dean of Admissions (and mechanical engineering alumnus) Stuart (Stu) Schmill, This subsection explores the undergraduate admissions process behind one of the world's most gender-balanced undergraduate engineering populations.

Admission rates at MIT are low: 7.8 percent of applicants were admitted for the Class of 2020, 8.0 percent the year before, and 7.7 percent two years prior (Gopinath).

6.4.1.1 Recruitment

A longstanding challenge in admitting minorities[34] is the lack of a diverse pool in the first place. How does MIT diversify its applicant pool?

Schmill said that one strategy the office uses when speaking at high schools is to highlight the gender balance at MIT as a means of cutting through stereotypes that a technical school like MIT would be female-unfriendly.

> When we are out recruiting, we try to make sure [the gender balance is] well known. And of course, it's when students come to visit… we really try to make sure that they're aware of that. They see it while they're here. That's the hard part, though, for us... because we have to fight against conventional wisdom.
>
> If you just take a random student, male or female, if they don't know much about us, they know MIT [as] this science, engineering [school]. They're going to think, "Oh, must be mostly men."
>
> Because again, we talked about the biases that young people are subjected to. So this is the conventional wisdom out there that we have to try to cut through, but it's really pervasive. Really pervasive. So that's why getting people to campus is so key for us.

[34] Although women are not statistically a minority in the society at large, they are often considered a social minority group as they deal with similar barriers as statistical minorities like African-Americans. At MIT, women are often still both a social minority group and a statistical minority group.

> It's why most of what our recruitment... tries to humanize MIT. So if you think about our admissions website, what is the center of that? The blogs.[35] It's the human voices, men and women, but describing what goes on here. That I think is like golden for us because the more people know about us, the more they like us. But we have a harder job communicating because we have to cut through these misperceptions that people have.
>
> —Stu Schmill
> Dean of Admissions

Of the 18 current student bloggers, 11 of them are female ("Student Bloggers").

> This isn't really policy, [but] it might be that we're more likely to visit an all-girls high school than we would be to visit an all-boys high school. I've been to some all-boys high schools, and we do visit, but we just might be more likely to visit an all-girls high school. That I think… is some manifestation of our desire to make sure we're speaking to women.
>
> Literally what we talk about [when we're visiting high schools] is the gender balance and how unique it is. We don't like to talk about other schools. But we really talk about how unique it is in those two ways, the fact compared to other liberal arts schools that young women are going to be in classes with other women here in ways that they might not [be] elsewhere… That is a very key message that we send.
>
> We feel like the best thing that we can do is to show the women that we have here who are doing it. That I think is the best way to send the message. Better than actually just saying it. Because when you tell somebody something is much different from when you actually show them. That's why it's important to both get students to come to campus, but also why I think our blogs are valuable.
>
> —Stu Schmill

MIT also hosts several programs to encourage female high school students to enter STEM. One example is the Math Prize for Girls, an annual math competition for female high school students that offers the world's largest monetary math prize for females ("Math Prize for Girls").

Another example is the Women's Technology Program (WTP) at MIT, which began in 2002 with the electrical engineering and computer science department. The summer program, exclusively for high school women, aims to encourage young women to pursue engineering and computer

[35] The MIT Admission Blogs are a collection of blog posts written by undergraduate students about their lives at MIT.

science studies and thus specifically targets smart women "who love and excel at math and science but have little or no background in engineering and computer science" ("WTP").

> We've been very supportive of the math department hosting on the MIT campus the Math Prize for Girls, for example. We're a big fan of the WTP program.
>
> On our website, we certainly publicize them. When the students are here, we'll have admissions officers go and talk with them so that we know that there's a connection to them. And also, in the selection process, not that we give an advantage to those students, but we know that students who went through that program have demonstrated some type of interest.
>
> One of [WTP's] missions is to enroll students that may not have been so focused on STEM up to that point because they're trying to increase the number of women in STEM. So that in some ways is a signal to us that, you know, if we don't see interest in STEM for these young women from, you know, a young age and yet now we see it, we believe it because we think, you know, maybe it was sparked here at our program.
>
> —Stu Schmill

6.4.1.2 Applicant Pool

While the applicant pool as a whole self-selects, Schmill said he found that the female applicants in some ways self-select at a higher rate than their male counterparts do.

> Most of the messages that we send about MIT are about not just how cool... the work is, but also about the fact that here at MIT, students and faculty work together to solve the big problems of the world and how you can come here and make a really big impact on the world.
>
> So I think those messages resonate with young women as much as young men... I think that may account for the fact that we have a fairly robust applicant pool.
>
> I actually think in some ways our applicant pool for a place like MIT is overrepresentative of women who express interest in majoring in STEM fields generally... and who have demonstrated, by taking some steps to participate in STEM.
>
> So the two examples are women who might take AP Computer Science. I think nationally, 19% of computer science, AP Computer Science, takers who score a 5 on the AP test are women. But a higher percentage of our applicant pool who've taken AP Computer Science are women. So there's an overrepresentation of women, stronger

> women, interested in computer science, who've taken computer science, are applying to MIT.
>
> Same thing is true of things like the math competitions, like the AMC (the American Math Competition) and then the next level, which is the American Invitational Math Exam.
>
> That doesn't mean that we're not, that we don't want to increase the number of women in our applicant pool. We certainly do. But we actually feel like we have a robust applicant pool.
>
> —Stu Schmill

According to the official website of the AMC and AIME's sponsoring organization, the Mathematical Association of America, more than 350,000 middle and high school students take the series of tests each year. A 2010 paper published in the *Journal of Economic Perspectives* by MIT professor Glenn Ellison and PhD student Ashley Swanson found a large gender gap at the highest scores, along with some other discrepancies:

"Whereas the boys come from a variety of backgrounds, the top-scoring girls are almost exclusively drawn from a remarkably small set of super-elite schools: as many girls come from the 20 schools that generally do best on these contests as from all other high schools in the United States combined. This suggests that almost all American girls with extreme mathematical ability are not developing their mathematical talents to the degree necessary to reach the extreme top percentiles of these contests."

In 2013, MIT added an option in its application for students to submit a "Maker Portfolio," designed to allow students to showcase their technically creative work, much like the supplements students could already submit for music, arts, and sports.

While thousands of students have taken advantage of this opportunity, women submit them at rates much lower than men do: only 2.8% of the female applicant pool submits Maker Portfolios, while 7.4% of the male applicant pool does. In other words, only 14.1% of the submitted Maker Portfolios are by women.

> Women are just less likely to submit a Maker Portfolio, so they're more likely to do things that would qualify as a maker and then not submit one. So there's some [discrepancy]... and so we've been thinking about this.

> Is it because the name of it? Is it because of our description? We describe, you know, what is this and who should submit. We really don't have the answer to it.
>
> —Stu Schmill

In the November/December 2015 MIT Faculty Newsletter, MIT Admissions Office Assistant Director Chris Peterson and MIT Electrical Engineering and Computer Science Professor Hal Abelson wrote that that emphasis on the "technical" creativity may have dissuaded some female applicants from submitting a portfolio.

"It's also possible that technically creative women may still not believe that the Maker Portfolio is 'for them,' despite specific actions taken by Admissions to try and counteract this belief," they wrote. On the other hand, women submit all other portfolios (research, performing arts, and art/architecture portfolios) at higher rates than men do.

> So yeah, if you read the faculty newsletter, basically we said we don't know why this is happening, but we posited a few reasons, you know. And I think a lot of this comes from the biases that women are subjected to from a very young age.
>
> —Stu Schmill

In an email followup, Boyce reflected on her own realization of her maker identity:

> Something that I had not realized until many years into my faculty career and that was pointed out to me by a design faculty colleague [was that] I was also a "maker" even in high school and I had not even appreciated that aspect of myself. In high school, I made most of my own clothes. I had been interested in this area and had to take sewing lessons (my mom did not sew) and buy my own machine, etc. [I] then started sewing my own clothes and eventually also designing some myself and sewing them. I did that for many years; now we all appreciate that element as being a "maker" due to the spatial capabilities, the design, the actually making etc.
>
> I have found it interesting to informally sample some of my women colleagues of my "age group" and have found that many had some element of this in their background as well—so while I always consider my interest in engineering to originate from my love of mathematics and physics, this other element of designing and making was also present (and yet I had never appreciated that as part of my path to engineering, yet it was another inherent element).
>
> —Mary Boyce

6.4.1.3 Admission

Fewer women apply to MIT than men do: in the 2014-2015 admissions cycle, 12,765 men and 5,591 women applied ("Common Data Set 2014-2015"). 740 men and 707 women were admitted, leading some critics to contend that the admissions standards are lower for women than they are for men.

Yet, as mentioned in the background section, women experience higher graduation rates and graduate with slightly higher average GPAs than men do.

> When we admit students, the metrics are the same, right, so male/female. There isn't a difference. But interestingly… women have higher graduation rates, right, from MIT… The students we're admitting are all equally academically and personally qualified and not just qualified, but are excellent. Because our applicant pool is so strong with enough very strong women applicants... when we admit our class, it is not quite but has been nearly half women over the last few years and that's been great.
>
> We're not trying to control that number [female to male undergraduate ratio]. I mean, if we were really trying to control it, we would just do it. Just get 50%. But we're not really trying to do that. We're still reliant or dependent on the strength of the applicant pool.
>
> —Stu Schmill

6.4.1.4 Yield

Encouraging women to apply and admitting them is only half the story—MIT also needs to convince them to come. According to an article in *The Tech*, MIT's student newspaper, the Class of 2019 saw a 73% yield (Gopinath).

> There are two things that really help us. One is that… most, I think like 85% plus or minus of our students, major in science or engineering... I think that helps us with women who are interested in majoring in science and engineering. They realize that… if they come to MIT, they're more likely to be in classes with other women. Whereas if they attend other universities that are not so centered on science and engineering where there may be gender balance, but… their science and engineering classes are very heavily male. Because we have much better gender balance in our science and engineering programs than just about anywhere.
>
> —Stu Schmill

MIT's Campus Preview Weekend used to only be for women and underrepresented minorities. 1999 was the first year that saw an integrated with Campus Preview Weekend, with all admitted students invited (Basu).

> That's why I think our applicant pool is so robust and our yield is very good, meaning the students we admit will choose to come. And that's true compared to other schools, like liberal arts schools that have science and engineering. But also we do better compared to other more science and engineering-centered places. Places like Caltech and Carnegie Mellon. There aren't too many other places that are quite like MIT, but Caltech is an example. We've had better gender balance than they have over time.

The Caltech Class of 2019 enrolled 46% women and 54% men, while their Class of 2018 enrolled 40% women to 60% men. The Class of 2017 saw an even larger gap: 35% women to 65% men ("Class of 2019 by the Numbers").

> And I think it's because women are more likely to choose to want to come to MIT because we are. It's a chicken and egg cycle, right. But I think that really helps us, and I do think we're in a relatively privileged position. I think other universities would love to be able to replicate, but I think have a harder time.
>
> —Stu Schmill

6.4.2 Media

The American popular media have not traditionally been at the vanguard of defying stereotypes. In a 1997 paper published in *Public Understanding of Science*, Western Michigan University Professor of Communication Jocelyn Steinke wrote that "the research literature indicates that media stereotypes of women scientists typically are reinforced in one of three ways: by downplaying the expertise of women scientists, by focusing on the conflicts faced by women scientists in balancing the demands of their professional and personal lives, and by presenting women scientists as lacking the masculine traits and skills needed to conduct scientific research."

Schmill said that he pays special attention to the messages the media sends to women because he has two daughters.

> Have you ever watched the *Big Bang Theory*? It's terrible. So I will tell you I think it's a funny show. I have never let my kids watch it because of the stereotypes. They are just awful. I mean, the women. There are two main character women. One is the sort of pretty one who is ditsy [and] doesn't know anything about math and science. And then there's the sort of frumpier one who is the scientist. It's just. Honestly you couldn't

> design a worse message... and then there are so many more examples of that kind of thing.
>
> —Stu Schmill

Big Bang Theory is a popular show series that follows the lives of two male physicists at Caltech, along with their friendships (and romantic relations) with women. In a 2014 paper published in the *Journal of Popular Film and Television*, "Representations of Female Scientists in The Big Bang Theory," Assistant Professor of Mass Media at Minnesota State University Heather McIntosh finds that "while on the surface some challenging and even undermining of these [gender] stereotypes do appear, those challenges remain short-lived in light of the situation comedy's goals to entertain while reinforcing the status quo."

> I think [sexism] occurs because we watch too much TV or video games or something and we develop these biases that should not exist but they do. When Hollywood does a movie, they like to do all kinds of [stereotypes]. You know, the movies are just filled with stereotypical characters. All Russians are hoods. I mean, it's ridiculous, you know. Leather jackets, bald, big—you're a bad guy. Gold chain—oh my God. [Laughter] Getting out of that mindset is just terrible and it's wrong, but you know, how do we fix it?
>
> So I think these biases are very, very hard to get rid of. And I think they're our natural tendency, and I think only through these mentorships or experiences like… interacting everyday with [my wife as] a scientist that I develop that attitude of "women do science." They're smart. They're competent. And I think that's the difference. I think these examples of role models and interacting with role models is where we finally break down our biases in our minds.
>
> —Doug Hart

> I'm a movie buff, and have a soft spot for sci-fi. My pet peeve are movies with female scientists. Usually, they look like supermodels, which is fine, but when they deliver the dialogue they just aren't very believable as scientists. It's embarrassing!
>
> —Maria Yang

6.4.3 Advice

At the end of interviews, interviewees were asked to give advice to potential female students interested in studying STEM subjects in college and going on to pursue a career in a technical field. Some generalized their advice to the system in general, while others offered direct advice to students themselves.

6.4.3.1 Direct Advice

Gallant directed her advice to students in general.

> Well, here's what I would say. I would say this to students in general, and I suppose it's good for women to hear this too: not to shy away from things that are hard. Things that are hard really make us discover what we're capable of. I chose my trajectory not necessarily because I loved mechanical engineering in the beginning, but because I wanted to challenge myself. And I thought I had the mind for it, but I wasn't sure. But I figured I'd start with the hardest thing I can come up with and if I can't do that, then I'll find something else that's more normal to do. [Laughter]
>
> Through that process, you don't have to start with full confidence. You don't have to start with complete knowledge. You don't have to start with a full set of skills. MIT specifically is a place that will give you all of those things.
>
> If anybody ever looks at me and sees me as some kind of role model, that's what I hope they'd understand... I wasn't born seeing myself as an engineer. I really worked for it, and I found a way to enjoy that.
>
> Oh, and that's another thing. When you finally get to a place in life where your confidence and your abilities and your interests all kind of jive together, then you can be really happy.
>
> What's really cool is that when you discover your mind likes to work on hard problems, the fact that it's science or technology almost doesn't necessarily matter. What you discover is that you like to think about things. And thinking in a way, and doing research, is our art.
>
> Artists get to do what they love, and paint or make music through their careers, and we get to solve questions and think about things from a technical point of view, in ways that help society and build new technologies. To me, that has its own true joy. I get to show up everyday and really do what I enjoy and what's interesting to me and what I think matters.
>
> When you realize that you can do that, that's such an amazing and empowering realization. You don't have to be someone who played with Legos since the time you were five years old or took apart toasters to be happy or successful in engineering. You can really be happy because you're able to be independent in your thinking, can teach and

> help others, and can use your knowledge to contribute to the world in the way that *you* think is most impactful.
>
> —Betar Gallant

Hughey chose to focus on the particular aspects that drew her to the mechanical engineering field.

> MechE is so cool. [Laughter] That's actually… the feeling, and hopefully we convey that in WTP.
>
> My feeling about MechE now is that it's like what physics was in the early 1900s. Physics has gotten so specialized with tunnel vision… But MechE, at least in this department, is like, "You can do anything." I mean look at what you're doing for your thesis. [Laughter]
>
> You can do anything. So I think MechE is a great place to start… I think once you have the technical background, you can really go do anything, you know. You don't have to keep doing engineering, although if you like it, you should. But you know, people go into finance… even just totally unrelated fields. The whole training, the how to think. It's more that it's teaching you how to think, and how to solve problems, and you can apply those to anything, whether it's engineering or not. So that's what I would say. [Laughter]
>
> —Barbara Hughey

6.4.3.2 Recommendations

START YOUNG

> While WTP is great and important, the problem starts in middle school. Possibly even before middle school, but especially middle school where again, because I was oblivious, I didn't notice. But that's where… it's not cool to be smart. It's not cool to be a girl and be smart. That's where girls tend to drop out. I think that's still true now.
>
> But given that, I think programs like WTP that address it in high school… are essential. Because once they turn away from the path, then you can't get back on it because it's too complicated... it's very hard once you fall off the technical track to get back on.
>
> —Barbara Hughey

A 2013 paper published in the *American Educational Research Journal* by University of Wisconsin-Madison professor Xueli Wang showed that "the effect of [high school] students' exposure to math and science courses is even stronger than that of math achievement, which was once deemed the single best predictor of students' future STEM entrance," which "implies that in order to boost high school students' interest in pursuing STEM fields of study, an earlier introduction and exposure to math- and science-related courses could be an effective method."

> STEM for women has to start early, I think. There are studies that say junior high is the magic age where girls stop engaging in math and science. I remember when I was in 7th grade there were a lot of girls in my advanced math class, and then 8th grade, BOOM, they disappeared. I didn't really understand why. I just knew something was weird.
>
> Anecdotally, I've found that women who make it to engineering grad school typically have a family member who is in a technical field, someone who can give them some guidance on how to proceed professionally and academically.
>
> —Maria Yang

As Steinke wrote in her 2005 paper "Cultural Representations of Gender and Science" published in *Science Communications,* "research shows that most girls first report a loss of interest in SET [science, engineering, and technology] during the middle school years, around the age of twelve, the same age at which many girls show a heightened awareness of gender roles. These events also coincide with the time when the media become more influential sources of information about gender for adolescents" (29-30).

DEMYSTIFY ENGINEERING

The capstone class in the mechanical engineering major at MIT is Product Engineering Processes (2.009). In the class, teams of 20 spend an intense semester designing and building an alpha prototype to be presented at the final showcase. Each team elects two leaders, called System Integrators (SIs). This past semester, 10 of the 18 SIs were female:

> This suggests that when we're talking about really doing engineering, which is what 2.009 is, the collective wisdom of the class says that women do very well at it, because we just had an election, and women were elected most of the time to do this role. So we have good reason to believe that women make excellent engineers because some of the smartest young people on the planet voted that they do. Without intending to, they just voted. That's what happened. And it's not the only year that that has happened. There's a message there.
>
> There are certainly not only good reasons to believe that women will make great engineers, but that things that women are good at and like to do probably prepare them well for engineering, so that seems to me to be the message we have to get across to

> women who are deciding about careers... and I think many of them would think that engineering is a lot more fun if they knew what it really was. Because 2.009 is exactly what engineering is. That's what you're going to do when you leave if you become an engineer. And it is fun. And it's exciting and it's thrilling. And that's not the message that we're sending to women, or to men for that matter, about what it means to be an engineer.
>
> So, how do we fix that? How do we get people to know what engineering really is, when even at MIT the myth is pretty strong? One thing that we could do is to help women understand what it really takes to be an engineer. And I think that they would find that it's quite well aligned with strengths that they bring and things that they already enjoy doing, but they just don't realize that that's what engineering is made up of.
>
> —Warren Seering

LEAKY PIPELINE

At the end of her interview, Hughey also brought up the leaky pipeline, a metaphor that refers to the loss of women along the STEM track, as an important problem to address.

> But then there's the secondary problem, which is something Dr. Wendell has probably talked to you about... it's been like this for a long time, that you lose them throughout the course of the PhD. And then they don't go into academia.
>
> I didn't go into academia and probably the main reason for that was I got my PhD when I was 29 and… I did want to have kids, and if you're going to go into academia, you need to get a temporary job. You need to get a postdoc or two postdocs, and then you get your academic position hopefully, but then that's temporary for seven years because you don't know if you have tenure, so I was like, "Yeah, no. No, I don't want to do this."
>
> So I think that's also a problem. I think it's affecting men too, but probably women more… The whole STEM education stuff and everything I think is getting better at the front end, but then I think at the higher degrees, we're still losing them at the back end and that's a quality of life kind of thing, I think.
>
> —Barbara Hughey

AWARENESS

Awareness of gender biases is the first step to addressing any kind of change. Harvard's Project Implicit offers 14 implicit association tests that help assess one's biases from topics ranging from race to religion to gender. According to the project's website, "the Implicit Association Test (IAT) measures attitudes and beliefs that people may be unwilling or unable to report" ("Project Implicit"). The gender-science one "often reveals a relative link between liberal arts and females and between science and males." After taking the test, survey participants are asked for demographic information to help inform research.

In a 2009 paper published in the *Proceedings of the National Academy of Sciences of the USA* (PNAS), researchers analyzed this data and found that "women who find it easier to associate men with science (and women with liberal arts) report less liking for math and science domains, less interest in pursuing science in the future, perform worse on standardized math exams like the SAT and ACT, and are less likely to be a math or science majors compared with women who do not have that association" (Nosek et al.).

This is significant because "about 70% of more than half a million Implicit Association Tests completed by citizens of 34 countries revealed expected implicit stereotypes associating science with males more than with females" (Nosek et al.).

> I think being aware of gender bias is important. And honestly, I think one way to start to grow awareness is to make everyone take the implicit bias test. We could recommend, that everyone at MIT take the implicit bias test once a year. You don't have to tell anyone what your score is. You just need that level of self-awareness. [Laughter]
>
> Let me tell you a funny story... I think this was in 2.001. I can't even remember [who] the student was. This was a male student who did not do well on the first exam. So I send out an email saying, "If you did not do well on the first exam, please come talk to me." So he did the right thing. He set up a meeting and came to talk to me. And I said, "What happened on the first exam?" And he said, "I don't know, I should have studied more." He said, "You know, I'm really embarrassed I did so badly on this exam. I looked at the exam of the person next to me and realized I did so badly that I was beat by a GIRL."
>
> And I'm looking at him. I'm looking at him. I'm LOOKING at him. [Laughter] And he's like, "OH. Oh. Sorry!" And you could see the awareness dawning on his face. So again, there's a level of self-awareness that people have to have that not everyone comes in with. Which is fine. People come to MIT out of high school with many different

backgrounds and experiences. But this is something they should learn while they are at MIT if they have not already learned it. And I think that guy learned it. [Laughter]

—Peko Hosoi

7. Conclusion

Over the past two decades, the Mechanical Engineering Department has made great strides in increasing the representation of undergraduate women at MIT. MIT has far exceeded the national average and even other peer schools when it comes to balancing the gender enrollment early and consistently, both at the school overall and within the Mechanical Engineering Department. While 46.4% of MIT's MechE department is female, nationally, only 13.5% of MechE bachelor's degrees go to women (Yoder). This achievement should not be taken for granted.

Through the data analysis of the departmental class enrollments and interviews of faculty and staff members, it has become apparent that the department has taken strong, identifiable steps over the years to promote gender equality in MechE. However, some of the largest elective classes still exhibit gender enrollment differences.

The data analysis of the elective classes showed that the 2.12 robotics class experienced a statistically significant trend of an increasing fraction of undergraduate women in the Mechanical Engineering Department taking the class over time, while the 2.14 controls, 2.72 mechanical design, and 2.96 management classes did not. Future work could delve into what factors may have influenced this particular increase in 2.12 through surveys or interviews with former students, TAs, and instructors of the class, in the hopes of replicating this increase in other subjects.

In addition, the data analysis revealed that a larger fraction of males in the department take the 2.12 robotics and 2.14 controls class than females do, but the 2.72 mechanical design and 2.96 management classes emerged gender-equal. Further data analysis could group the elective classes into subfields (e.g. mechanics, controls, bioengineering, etc.) or class structure (project-based, lecture-based, etc.) and analyze them based on these categories. Women's self-selection into classes is important because the choices reveal preferences that, if not biological, may stem from social pressures worth studying in further detail.

Thematic analysis of interviews reveals that the gender equality so far achieved by the department has been a result of very deliberate structural changes, (e.g. hiring processes), and a strong representation of proactive department members with high levels of self-efficacy—they are both aware of gender issues and believe in their ability to enact change. Different but complementary actions, from changing the way the admissions office recruits admissions candidates to the careful balancing of teams in group work classes, have compounded over time to produce the current state of near parity.

These background interviews have contextualized the department's remarkable rise in undergraduate female enrollment and can help inform future studies on the matter. Surveys and interviews with alumni, particularly from the years in which the undergraduate female enrollment in the mechanical engineering department spiked, are recommended to look into why and how the undergraduate mechanical engineering population has reached near parity.

Continued longitudinal research that tracks alumni's career paths over time would complement this subject well. In addition, publicly available data from the enrollment statistics could be analyzed to see which of the departments dropped in female enrollment to supply mechanical engineering's increase in female enrollment. Finally, more MechE faculty members, teaching assistants, and lab instructors could be interviewed on the subject of gender in the department.

For any school, department, or individual who prioritizes achieving gender balance in the STEM fields, these findings should provide—as in the memorable words of one interviewee—an existence proof that this gender equality is not just possible, but possible *today*. It will take *mens, manus*, and a different application of the problem-solving skills that engineers traditionally learn.

Appendices

Appendix A: Female Faculty Percentage Over Time

Data provided by Lydia Snover of MIT's Office of Institutional Research.

MIT Engineering					
	Count			Percent	
	Men	Women	Total	Men	Women
1983	361	10	371	97%	3%
1984	364	9	373	98%	2%
1985	361	9	370	98%	2%
1986	359	11	370	97%	3%
1987	374	16	390	96%	4%
1988	367	20	387	95%	5%
1989	371	21	392	95%	5%
1990	356	23	379	94%	6%
1991	356	22	378	94%	6%
1992	353	23	376	94%	6%
1993	347	23	370	94%	6%
1994	357	26	383	93%	7%
1995	333	24	357	93%	7%
1996	335	28	363	92%	8%
1997	297	30	327	91%	9%
1998	309	31	340	91%	9%
1999	305	32	337	91%	9%

2000	314	31	345	91%	9%
2001	316	34	350	90%	10%
2002	319	35	354	90%	10%
2003	322	40	362	89%	11%
2004	317	45	362	88%	12%
2005	325	51	376	86%	14%
2006	324	52	376	86%	14%
2007	327	53	380	86%	14%
2008	325	53	378	86%	14%
2009	323	51	374	86%	14%
2010	320	57	377	85%	15%
2011	316	62	378	84%	16%
2012	316	64	380	83%	17%
2013	319	64	383	83%	17%
2014	318	66	384	83%	17%
2015	310	68	378	82%	18%
2016	311	67	378	82%	18%
Figures are based on faculty census taken in October of each academic year.					

MIT Science					
	Count			Percent	
	Men	Women	Total	Men	Women
1983	261	19	280	93%	7%
1984	262	17	279	94%	6%

1985	257	18	275	93%	7%
1986	255	18	273	93%	7%
1987	256	16	272	94%	6%
1988	251	19	270	93%	7%
1989	243	18	261	93%	7%
1990	245	16	261	94%	6%
1991	239	16	255	94%	6%
1992	233	18	251	93%	7%
1993	234	20	254	92%	8%
1994	233	18	251	93%	7%
1995	252	22	274	92%	8%
1996	259	23	282	92%	8%
1997	242	23	265	91%	9%
1998	233	28	261	89%	11%
1999	235	30	265	89%	11%
2000	229	34	263	87%	13%
2001	229	34	263	87%	13%
2002	228	32	260	88%	12%
2003	232	34	266	87%	13%
2004	235	35	270	87%	13%
2005	233	35	268	87%	13%
2006	240	36	276	87%	13%
2007	234	39	273	86%	14%
2008	236	45	281	84%	16%

2009	233	48	281	83%	17%
2010	229	52	281	81%	19%
2011	224	52	276	81%	19%
2012	223	50	273	82%	18%
2013	223	51	274	81%	19%
2014	224	54	278	81%	19%
2015	222	52	274	81%	19%
2016	219	54	273	80%	20%
Figures are based on faculty census taken in October of each academic year.					

Appendix B: Caltech Gender Enrollment

Data provided by Mary Morley from the Caltech Office of the Registrar.

Option	UG F	UG M	UG Total	GR F	GR M	GR Total	Grand Total
Aeronautics				5	42	47	47
Aerospace				4	3	7	7
Applied & Computational Math	17	25	42		13	13	55
Applied Mechanics				1	3	4	4
Applied Physics	4	12	16	10	50	60	76
Astrophysics	8	8	16	18	13	31	47
Behavioral and Social Neuroscience				2	1	3	3
Biochemistry & Molecular Bioph				19	26	45	45
Bioengineering	30	20	50	10	32	42	92
Biology	23	10	33	27	48	75	108
Business Economics & Management		1	1				1
Chemical Engineering	23	34	57	15	39	54	111
Chemistry	25	21	46	77	120	197	243
Civil Engineering				2	14	16	16
Computation and Neural Systems				4	27	31	31
Computer Science	46	131	177	3	6	9	186
Computing & Math Sciences				1	9	10	10
Control & Dynamical Systems				7	14	21	21
Economics	1		1				1
Electrical Engineering	30	48	78	17	92	109	187

Engineering and Applied Science	8	8	16				16
English	1	1	2				2
Environmental Science & Eng				14	13	27	27
Geobiology	3		3	4	4	8	11
Geochemistry	2	1	3	4	12	16	19
Geology	2	2	4	7	11	18	22
Geophysics	1	3	4	6	16	22	26
History & Philosophy of Sci	1		1				1
Materials Science				23	45	68	68
Mathematics	9	33	42	5	33	38	80
Mechanical Engineering	26	59	85	11	39	50	135
Medical Engineering				4	6	10	10
Neurobiology				4	7	11	11
Physics	16	60	76	21	120	141	217
Planetary Science	2	3	5	8	13	21	26
Social Science				8	23	31	31
Space Engineering				5	14	19	19
Undeclared	113	130	243				243
Grand Total	**391**	**610**	**1001**	**346**	**908**	**1254**	**2255**

Appendix C: Elective Classes Instructors List

List provided by Brandy Baker, MIT Department of Mechanical Engineering's Undergraduate Academic Administrator.

2.12 (Introduction to Robotics)
Fall 2004 Asada
Fall 2005 Asada and Leonard
Fall 2006 Asada (Ueda as Lab Instructor)
Fall 2007 Asada (Wiesman as Lab Instructor)
Fall 2008 Asada (Chin as Lab Instructor)
Fall 2009 Leonard (Chin as Lab Instructor)
Fall 2010 Asada (Chin as Lab Instructor)
Fall 2011 Asada (Chin as Lab Instructor)
Fall 2012 Asada (Youcef-Toumi as Lab Instructor)
Fall 2013 Asada (Youcef-Toumi as Lab Instructor)
Fall 2014 Asada (Youcef-Toumi as Lab Instructor)
Fall 2015 Asada (Youcef-Toumi as Lab Instructor)

2.14 (Analysis and Design of Feedback Control Systems)
Spring 2006 Youcef-Toumi
Spring 2007 Trumper (Nayfeh as Lab Instructor)
Spring 2008 Slotine (Youcef-Toumi as Lab Instructor)
Spring 2009 Youcef-Toumi (Trumper as Lab Instructor)
Spring 2010 Slotine (Youcef-Toumi as Lab Instructor)
Spring 2011 Trumper (Youcef-Toumi as Lab Instructor)
Spring 2012 Slotine
Spring 2013 Youcef-Toumi (Trumper as Lab Instructor)
Spring 2014 Trumper
Spring 2015 Trumper

2.72 (Elements of Mechanical Design)
Spring 2004 Frey, D. Hart & Leonard
Spring 2006 Frey (Amy Smith as Lab Instructor)
Spring 2007 Culpepper
Spring 2008 Culpepper
Spring 2009 Culpepper
Spring 2010 Culpepper
Spring 2011 Culpepper
Spring 2012 Culpepper
Spring 2013 Culpepper
Spring 2014 Culpepper

Spring 2015 Culpepper

*Note from Baker: Bill Buckley has been the Lab Instructor for this subject for some time, but is not always noted in the teaching assignments as he is MechE Staff.

2.96 (Management in Engineering)

Fall 2004 Chun & D'Arbeloff
Fall 2005 Chun
Fall 2006 Chun
Fall 2007 Chun
Fall 2008 Chun & Marcus (Weiss as Lab Instructor)
Fall 2009 Chun & Marcus
Fall 2010 Marcus & Weiss
Fall 2011 Chun & Marcus
Fall 2012 Chun & Marcus
Fall 2013 Chun & Weiss
Fall 2014 Weiss, Foley, Tulloch & Turner
Fall 2015 Chun & Weiss

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