Study on the Careers of MIT Mechanical Engineering Undergraduate Alumni

by

Kelly Wang

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

Bachelor of Science in Mechanical Engineering

at the

Massachusetts Institute of Technology

June 2015

Signature of Author: Signature redacted
Department of Mechanical Engineering
May 8, 2015

Certified by: Signature redacted
Warren Seering
Weber-Shaughness Professor of Mechanical Engineering
Thesis Supervisor

Accepted by: Signature redacted
Anette Hosoi
Professor of Mechanical Engineering
Undergraduate Officer

Study on the Careers of MIT Mechanical Engineering Undergraduate Alumni

by

Kelly Wang

Submitted to the Department of Mechanical Engineering
on May 8, 2015 in Partial Fulfillment of the
Requirements for the Degree of

Bachelor of Science in Mechanical Engineering

ABSTRACT:
The purpose of this study is to understand the skills used in the professional field in order to tailor the MIT undergraduate curriculum to address those needs. Data was collected through a survey sent to the graduating classes of 1992 through 1996, 2003 through 2007, and 2009 through 2013 in order to get a range of responses. The survey focused on topics pertaining to technical knowledge, engineering skills, work environment skills, and professional attributes. The questions focused on frequency of use, expected proficiency, and source of knowledge of these topics. Results of the data were categorized by frequency, proficiency, and source, as well as by occupation and graduating year.

Responses show a lower frequency of use for the technical reasoning knowledge and a high frequency of use for communication-based skills. However, this is because technical knowledge is considered valuable to a specialized group of people, whereas the work environment skills are more career-independent. One method of addressing this observation is to balance out the number of lecture-based classes and project-based classes.

Additional interpretations of the data, along with their implications on the curriculum, are discussed in more detail.

Thesis Supervisor: Warren Seering
Title: Weber-Shaughness Professor of Mechanical Engineering

Special Thanks to:
Joseph Seering, Jagruti Patel, the Office of Institutional Research, the MIT Mechanical Engineering department for their help with the creation and distribution of the survey.

Professor Warren Seering for his enthusiasm and support in making this study possible in addition to his incredible insight on the project based on previous studies.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

Goals of the Study

The objective of this study is to gather information on the professional skills of the MIT Mechanical Engineering alumni in order to understand the knowledge and skills utilized in the workplace.

The gathered information is then analyzed in order to better understand the important skills needed in the professional field as well as common career paths. The purpose of this study is to apply this information towards the Mechanical Engineering curriculum, so that the knowledge and skills taught in the undergraduate coursework accurately reflect the needs of professionals in similar careers. Additionally, this information will be extremely relevant for current mechanical engineering undergraduates as they start their personal career paths. We intend to make this information easily accessible to current undergraduates in the hope that they can make more informed decisions about their own career directions and better understand the specific tasks that certain careers entail.

Background

In 2004, Kristen Wolfe focused her undergraduate thesis on the knowledge and skills of MIT Mechanical Engineering alumni, entitled "Understanding the Careers of the Alumni of the MIT Mechanical Engineering Department". In this study, Kristen Wolfe and her thesis advisor Professor Warren Seering collected data from the graduating classes of 1992 through 1996, inquiring about the knowledge and skills utilized in their professions. The data was divided into four categories: technical knowledge and reasoning, personal and professional skills and attributes, interpersonal skills, and engineering skills. Alumni were asked about expected proficiency, frequency of use, and source of knowledge for each of these categories. Kristen observed a low frequency of use and expected proficiency in the technical areas of knowledge, while teamwork and communication were most commonly used. Through these observations, Kristen suggested an integration of these skills into the core requirements. For more information on Kristen Wolfe's thesis, see Appendix 1.

This study follows Kristen's research method closely in the hopes of confirming the implications of her findings. In addition, one of the goals of this study was to learn about the career paths of alumni over time, further understanding the evolution of their roles in the workplace as well as the type of tasks they perform on a daily basis.

Previous Research

On top of Kristen Wolfe's research, there have been several other studies focused on the curriculum and career paths. In 2003, Catherine Kelly studied the career paths that MIT undergraduates pursued over a span of 35 years entitled "Some Trends in the Career Paths Followed by Alumni of the MIT Mechanical Engineering

Department". In Catherine's study, which surveyed the graduating classes of 1967 to 2002, she concluded that approximately two-thirds of each graduating class becomes engineers and managers. As the number of years since graduation increases, the percentage of engineers decreases while the percentage of managers increases.

In 2010, Neha Batra focused on the career paths of alumni, and how their undergraduate experience prepared them for their jobs. In her study, entitled "A Look to the Future: MIT Alumni and their Course 2 and 2-A Educational Experience", Neha compared the preparedness of those who graduated with a Course 2 degree with those who graduated with a Course 2-A degree. In a survey sent out to the graduating classes of 1999-2009, Neha asked about the importance and how well MIT prepared them in specific skills. Similar to Kristen's conclusions, Neha observed an emphasis on the communication and leadership skills, whereas the technical and economic skills were the least important.

Chapter 2: The Survey

The Foundation

The foundation of the research method was based on the 2004 survey that Kristen Wolfe developed in her study. Wolfe's survey, which was based on previous research done by Professor Edward Crawley in the department of Aeronautics and Astronautics, divided the knowledge and skills in question into four categories: technical knowledge and reasoning, personal and professional skills and attributes, interpersonal skills, and engineering skills. Each of these categories was then subcategorized further into topics: the technical knowledge and reasoning section focused on the topics covered in the required classes for a mechanical engineering degree, while the remaining three categories were largely based on Prof. Crawley's previous research, entitled "The CDIO Syllabus: A Statement of Goals for the Undergraduate Engineering Education". The format created by Wolfe can be seen below:

1) Technical Knowledge and Reasoning
    a. Underlying Sciences
    b. Underlying Mathematics
    c. Mechanics of Solids
    d. Mechanical Behavior of Materials
    e. System Dynamics and Control
    f. Dynamics
    g. Fluid Mechanics
    h. Thermodynamics
    i. Heat Transfer
    j. Engineering Design Process
    k. Manufacturing
2) Personal and Profession Skills and Attributes
    a. Engineering Reasoning and Problem Solving
    b. Experimentation and Knowledge Discovery
    c. System Thinking

d. Personal Skills and Attributes
e. Professional Skills and Attributes
f. Independent Thinking

3) Interpersonal Skills
   a. Teamwork
   b. Communication
4) Engineering Skills
   a. External and Societal Context
   b. Enterprise and Business Context
   c. Market Context
   d. Developing an Idea
   e. Designing
   f. Testing

For each of these topics, Wolfe focused on the expected proficiency, the frequency of use, and the source of knowledge. The scales used for each of these questions were:

Expected Proficiency
- To have experienced or been exposed to
- To be able to participate in and contribute to
- To be able to understand and explain
- To be skills in the practice or implementation of
- To be able to lead or innovate in

Frequency of Use
- Never
- Hardly ever- a few times a year
- Occasionally- at least once a month
- Regularly- at least weekly
- Frequently- on most days
- Pervasively- for almost everything I do

Source
- U- Undergraduate Program at MIT
- G- Graduate School
- J- Job
- E- Somewhere Else
- N- Did Not Learn

For further details on the survey that Wolfe sent in her study, please see Appendix 2.

The rationale behind keeping the majority of the 2004 survey intact was so that we would have the opportunity to compare the data between Wolfe's survey and the new survey. With these intentions in mind, the exact scales were used for the *expected proficiency* and *frequency of use* portions of the survey. Additionally, the topics and were taken directly from the 2004 survey, with some minor changes.

Modifications to the Survey

There were a few changes made based on feedback and discussions with the Office of Institutional Research and beta testers. One noticeable change was the re-categorization of the subject blocks. The Technical Knowledge category stayed relatively untouched, with the exception of the merging of *System Dynamics and Control* and *Dynamics* into *System Dynamics* in part 1e. The rest of the blocks were reorganized, however the topics themselves still remained the same. This was done to increase understandability while still keeping the fundamental questions the same for comparison purposes. For example, the Engineering Skills category was moved immediately after the Technical Knowledge block to create a more fluid structure. Within this block, the topics of Engineering Reasoning, Experimentation, and System Thinking were added. In addition, the topic of leadership was added under the *Work Environment* section. We found it important to distinguish the skill of leadership from teamwork, as the MIT undergraduate program has been putting significant effort into developing these skills in programs such as the Undergraduate Practice Opportunities Program (UPOP) and the Gordon-MIT Engineering Leadership (GEL) program.

A full list of the changes can be seen below, marked with an asterisk (*). It is noted that because of the reorganization of the questions, order effects would need to be taken into account for any variation in the results. When discussing results, I will refer back to these subject blocks, as they provide a structure for the twenty-five individual topics.

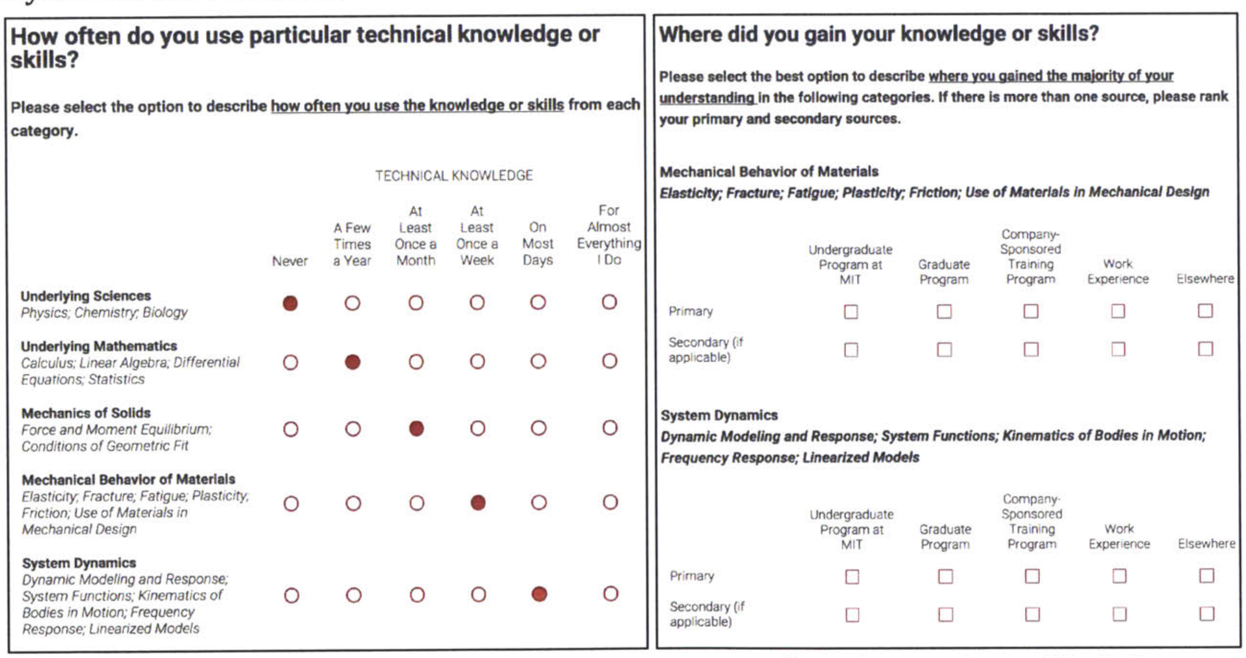
1) Technical Knowledge
   a. Underlying Sciences
   b. Underlying Mathematics
   c. Mechanics of Solids
   d. Mechanical Behavior of Materials
   e. System Dynamics*
   f. Fluid Mechanics
   g. Thermodynamics
   h. Heat Transfer
   i. Engineering Design Process
   j. Manufacturing
2) Engineering Skills*
   a. Engineering Reasoning*
   b. Experimentation*
   c. System Thinking*
   d. Idea Development
   e. Designing
   f. Testing
3) Work Environment*
   a. Independent Thinking*
   b. Teamwork
   c. Leadership*
   d. Communication
4) Professional Skills and Attributes*
   a. Personal Skills
   b. Professional Attributes
   c. External and Societal Context*
   d. Business Context*
   e. Market Context*

Each of these topics included a short description in order to ensure that the respondents' interpretations were similar. A detailed list of the topics and their descriptions can be found in Appendix 3.

Learning from the 2004 survey, the source question was altered in order to get a more meaningful response. In order to reduce the length of the survey and to eliminate any irrelevant questions, a conditional logic was added to the source question. Since we were only interested in the source of knowledge if the individual used the skill frequently, the source question was only asked for the topics where the respondent answered *At Least Once a Week, On Most Days,* and *For Almost Everything I Do*. Therefore, the *Did Not Learn* option was removed from the multiple-choice selection. To achieve a higher level of detail, the *Job* option was split into two in order to distinguish a formal training program from an informal on-the-job project. We were interested in further understanding the methods that people learned certain skills: whether it was from a structured class setting or hands-on experience. The modified list of options was chosen to be:

Source
- Undergraduate Program at MIT
- Graduate Program
- Company-Sponsored Training Program*
- Work Experience*
- Elsewhere

Also based on feedback from past surveys and alumni, the option of a secondary source response was added. A screenshot of the conditional logic and the survey layout can be seen below.


How often do you use particular technical knowledge or skills?

Please select the option to describe how often you use the knowledge or skills from each category.

TECHNICAL KNOWLEDGE

	Never	A Few Times a Year	At Least Once a Month	At Least Once a Week	On Most Days	For Almost Everything I Do
Underlying Sciences *Physics; Chemistry; Biology*	●	○	○	○	○	○
Underlying Mathematics *Calculus; Linear Algebra; Differential Equations; Statistics*	○	●	○	○	○	○
Mechanics of Solids *Force and Moment Equilibrium; Conditions of Geometric Fit*	○	○	●	○	○	○
Mechanical Behavior of Materials *Elasticity; Fracture; Fatigue; Plasticity; Friction; Use of Materials in Mechanical Design*	○	○	○	●	○	○
System Dynamics *Dynamic Modeling and Response; System Functions; Kinematics of Bodies in Motion; Frequency Response; Linearized Models*	○	○	○	○	●	○

Where did you gain your knowledge or skills?

Please select the best option to describe where you gained the majority of your understanding in the following categories. If there is more than one source, please rank your primary and secondary sources.

Mechanical Behavior of Materials
Elasticity; Fracture; Fatigue; Plasticity; Friction; Use of Materials in Mechanical Design

	Undergraduate Program at MIT	Graduate Program	Company-Sponsored Training Program	Work Experience	Elsewhere
Primary	☐	☐	☐	☐	☐
Secondary (if applicable)	☐	☐	☐	☐	☐

System Dynamics
Dynamic Modeling and Response; System Functions; Kinematics of Bodies in Motion; Frequency Response; Linearized Models

	Undergraduate Program at MIT	Graduate Program	Company-Sponsored Training Program	Work Experience	Elsewhere
Primary	☐	☐	☐	☐	☐
Secondary (if applicable)	☐	☐	☐	☐	☐

Figure 1: Source of Knowledge Conditional Logic. For topics where *At Least Once a Week, On Most Days,* or *For Almost Everything I Do* were chosen (L), source of knowledge was asked (R).

At the end of Wolfe's survey, the person was asked to specify their current occupation. They could self-categorize themselves as an engineer, a manager, a consultant, etc. A full list of occupations can be found in Appendix 4. However, in order to get a more detailed description of a person's occupation, this question was also significantly modified. In an attempt to find the best approach to this common question, I looked at past alumni surveys sent by the Office of Institutional Research to the MIT alumni. Looking at the surveys sent out institute-wide in 2005, 2009, and 2013 (alumni surveys are sent out every four years) the occupation question was differently phrased and laid out every time, thereby confirming that there is not a straightforward way to ask the simple question. There were some slight modifications and additions to the occupation list, which can be found in Appendix 5. For the purposes of this survey, the focus was to further categorize the engineers, managers, and consultants, as those were the most commonly chosen answers in previous results. In order to do this, another conditional logic was added.

If *Engineer* or *Manager* was selected as a person's occupation, then the next question asked about the person's primary area, and the following list was presented:

- Manufacturing
- Software
- Engineering Systems
- Product Design and Development
- Technical Support
- Quality
- Research
- Facilities
- Project Manager
- Program Manager
- Business Development
- Marketing and Sales
- Finance
- Engineering Manager
- Executive
- Other- Please Specify

If *Consultant* was selected as a person's occupation, then the next question asked about the person's primary role:

- Engineering Consultant
- Management Consultant
- Financial Consultant
- Medical Consultant
- Other- Please Specify

These subcategories were compiled from a variety of public lists on the most popular areas of mechanical engineering and consulting. Because a large portion of alumni become technical managers and some project managers identify as engineers, the follow-up question for engineers and managers was combined into one.

In addition to the current occupation question set, each person was also asked about his or her first occupation after graduating with a Bachelor of Science from MIT. *Same as Current Occupation* was added to the list of answers, while *Doctor, Attorney,* and *Professor* were removed from the list. The same conditional logic described above was added after this question as well. If *Same as Current Occupation* was selected, the respondent skipped any follow-up questions on specific roles, regardless of their current occupation. The combination of these two responses was used to get a brief glimpse at our alumni's various career paths and how they changed over time. To further elaborate on an individual's career path, every individual was asked how many companies they have worked at, the number of years spent at their current company and what further degrees they received. These questions were asked in order to get a sense of the geographical stability of a certain type of career path as well as further education required.

Another addition to the survey was focused on the specific tasks that a person performs on a weekly basis to answer the age-old question, "What does an engineer do during a typical week?" There were three main categories: *Communicating and Interacting, Planning and Designing,* and *Creating or Modifying*. The individual was asked to select all the tasks that they spent more than five hours on during the past week. A full list of the tasks can be found in Appendix 6.

Lastly, at the end of the survey, people were left with open-ended questions to leave any last remarks. There were three questions asked, with text box answers. They were:

- "What aspects in your MIT experience have been most valuable to you professionally?"
- "If applicable, how did your college internships influence your career decision?"
- "Faculty from the MIT Schools of Engineering and Management are considering the possibility of offering continuing professional education opportunities for alumni, in formats including online classes, resident short courses, and degree programs. If MIT were to offer courses such as these, what topics would you like to see included?"

The survey underwent multiple revisions before reaching its final state. Feedback was taken from Professor Seering, the Office of Institutional Research, and the Leaders in Global Operations (LGO) community. The survey was beta-tested in order to confirm readability and to get a reasonable estimate of the time required to take the survey. The comments and suggestions from these different perspectives helped create a comprehensive and succinct final survey. A complete copy of the final survey sent can be seen in Appendix 7.

<u>Distributing the Survey</u>

The survey was sent out through the Office of Institutional Research to all of the MIT Mechanical Engineering alumni in the graduating classes of 1992 to 1996, 2003 to 2007, and 2009 to 2013. These three ranges were chosen because we wanted to look at the evolution of responses of graduates approximately 5, 10, and 20 years out of college. Note that the 1992 to 1996 graduating classes are the same group of people that Wolfe reached out to in her survey, and the 2003 to 2007 graduating classes are the equivalent age group that Wolfe focused on in her study. In total, the survey reached approximately 1800 individuals by email on March 27, 2015. Those who didn't respond within a week and a half were sent a follow-up reminder email. A final third reminder was sent out three weeks later as a last effort to get as many responses as possible. As of May 7, 2015, 768 people responded to the survey, resulting in a 42.7% response rate. Please note that the third wave of responses are not fully included in this analysis plots due to time constraints, however 583 filled out the survey after the first reminder email, a 32.4% response rate. Therefore conclusions can be drawn from the 583 responses that provide a basic generalization of the population. The third wave of responses was kept for future research in the topic. The content of the email correspondence can be found in Appendix 8.

Chapter 3: Data Analysis and Interpretations

In this next chapter, I will go through the results that I found particularly relevant from the survey responses, represented through graphs and charts plotted in Excel. Please note that the following graphs serve only as a fraction of the many ways to visualize the data. Because of the abundance of information gathered from the survey and the time constraint of a thesis, there are additional observations that can be drawn from the data that I will not cover, but I do hope that they will be covered in future research. I will focus on the most interesting topics that I have found during my analysis, as well as the most relevant correlations for the objective of this thesis—the mechanical engineering department's curriculum. This data is meant to serve as a stepping-stone for further investigation and discussion on the topic. Throughout the analysis, I will include my own interpretation on the subject matter, with the understanding that I am not an expert in the curriculum aside from my personal experience as a student.

Using a program called Statistical Package for the Social Sciences (SPSS), I was able to analyze the 583 responses more easily. The 'Crosstabs' function was used to find the number of times a certain response was selected. Additionally, the responses could be categorized by a respondent's graduating year or occupation, if needed. The CSV files were then exported into Excel in order to obtain plots of the responses.

Frequency of Use

First looking at frequency of use, I found the frequencies of each response using SPSS. Exporting the table into Excel and plotting it in a stacked bar graph, the following graph was generated. The bar graph is done in percentages in order to normalize the different categories, since the total number of responses varied slightly (from 542 to 550 responses). On the left hand side, the topics are sorted by a cumulative sum of the *At Least Once a Week, On Most Days,* and *For Almost Everything I Do* responses, in descending order. This was chosen to be the cutoff since the conditional logic for the source question focused on these three responses. However, one could choose to include the *At Least Once a Month* response in the cumulative sum, and the topics would only move slightly—up or down by a maximum of three (and that occurs only once: *Testing* moves up by three). The first two topics, *Personal Skills* and *Independent Thinking*, would remain the same. The number inside each bar represents the number of responses for each respective question.

As seen in the chart, the most frequently used skills are:

1. Personal Skills
2. Independent Thinking
3. Professional Attributes
4. Communication
5. Teamwork
6. Engineering Reasoning
7. Leadership

After these seven topics, there is a significant gap (approximately 25%) based on the *At Least Once a Month* (Green) and *At Least Once a Week* (Purple) division. In these top seven topics, all four of the Work Environment topics *(Independent Thinking, Teamwork, Leadership*, and *Communication*) are included, as well as the *Personal Skills* and *Professional Attributes* portion of the Professional Skills and Attributes subject block. According to the dictionary, *knowledge* is the theoretical or practical understanding of a subject, while *skills* are the proficiencies developed through training or experience. These most frequently used topics would be considered skills as opposed to knowledge. Therefore they tend to be used more frequently, in combination with the use of knowledge.

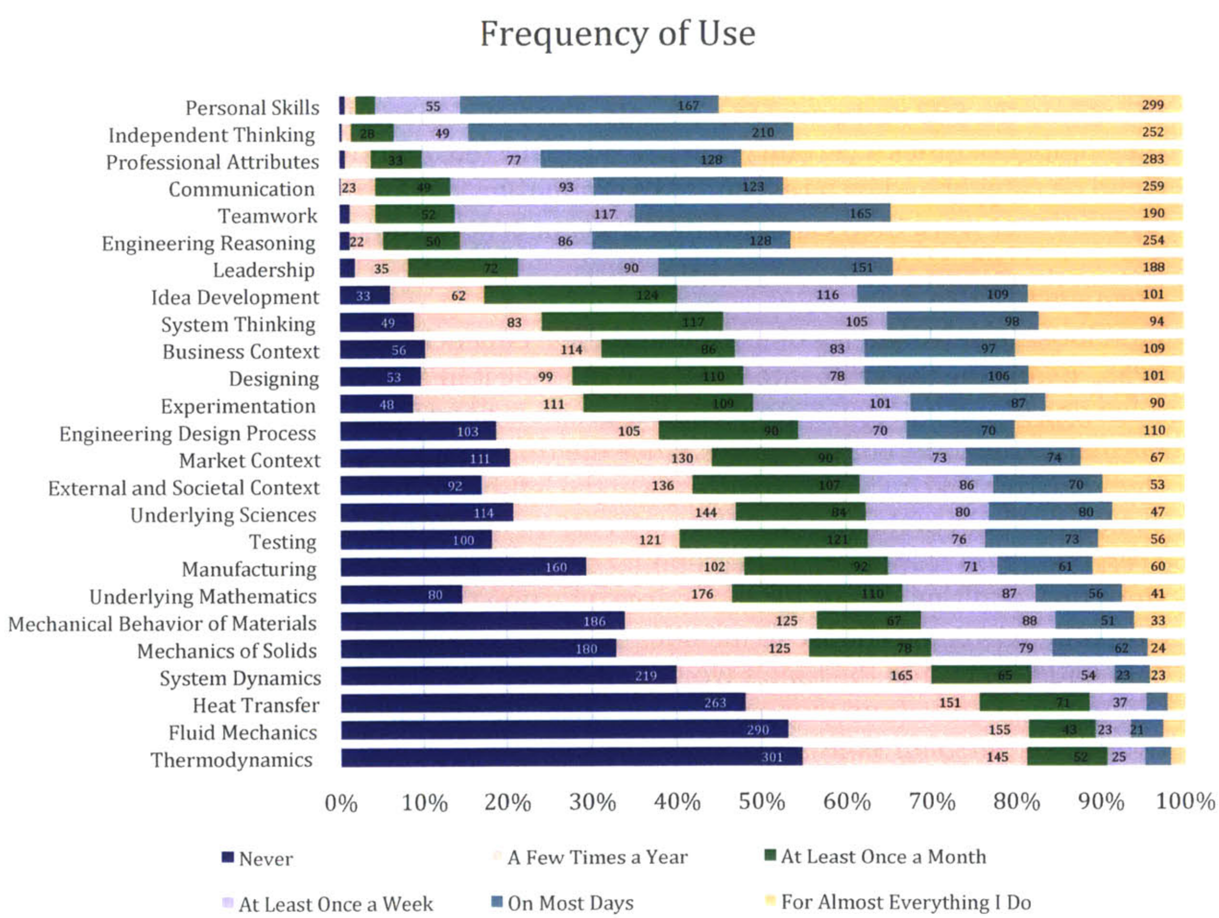


Figure 2: Frequency of Use Bar Chart, most frequently used to least frequently used.

The next subsection of topics that is frequently used includes:

8. Idea Development
9. System Thinking
10. Business Context
11. Designing
12. Experimentation

While the gap between *Engineering Design Process* and *Market Context* is not as significant as before (approximately 7%), the gap between *Experimentation* and *Market Context* is more noticeable (11%) and I have arbitrarily chosen to include *Engineering Design Process* with the third grouping.

This second grouping includes the majority of the Engineering Skills block (*Idea Development, System Thinking, Designing,* and *Experimentation*), in addition to *Business Context.* It is interesting to note that of the three remaining topics in the Professional Attributes subject block (*Business Context, Market Context,* and *External and Societal Context*) the *Business Context* is used significantly more than the other two.

The rest of the topics can be divided once more:

13. Engineering Design Process
14. Market Context
15. External and Societal Context
16. Underlying Sciences
17. Testing
18. Manufacturing
19. Underlying Mathematics
20. Mechanical Behavior of Materials
21. Mechanics of Solids

22. System Dynamics
23. Heat Transfer
24. Fluid Mechanics
25. Thermodynamics

All ten topics of the Technical Knowledge subject block are included in this last half. *Engineering Design Process* is the first Technical Knowledge topic to show up on the rankings. Please note that, similar to *Engineering Reasoning*, *Engineering Design Process* is the first of its subject block to appear on the list. Both are noticeably more used than their counterparts. The description of *Engineering Design Process* possesses similar attributes to the descriptions of both *Designing* and *Testing*, and lies in between these two topics on the chart.

The four least frequently used topics are four of the more advanced technical topics, corresponding to the higher-numbered Mechanical Engineering courses that MIT students tend to take as an upperclassman (2.004 – 2.006). Meanwhile, the Technical Knowledge topics in the third grouping correspond to the GIRs and the first Mechanical Engineering courses that undergraduates typically take, because they form the foundation for a solid mechanical engineering background. Therefore, because the knowledge of the more advanced topics is more specialized, it is understandable that they are used in more specialized jobs, where only a select few use them frequently.

Expected Proficiency

The Expected Proficiency stacked bar chart was produced using the same method as the Frequency of Use chart. On the left hand side, the topics are sorted by a cumulative sum of the *To be able to participate and contribute to, To be able to understand and explain, To be skilled in the practice and implementation of,* and *To be able to innovate and lead in* responses, in descending order. This cutoff was chosen because all four of these responses implied a sufficient knowledge of the topic such that the person was comfortable using the skill in practice. The top four topics, Communication, Personal Skills, Independent Thinking, and Teamwork, differ by a total of four responses.

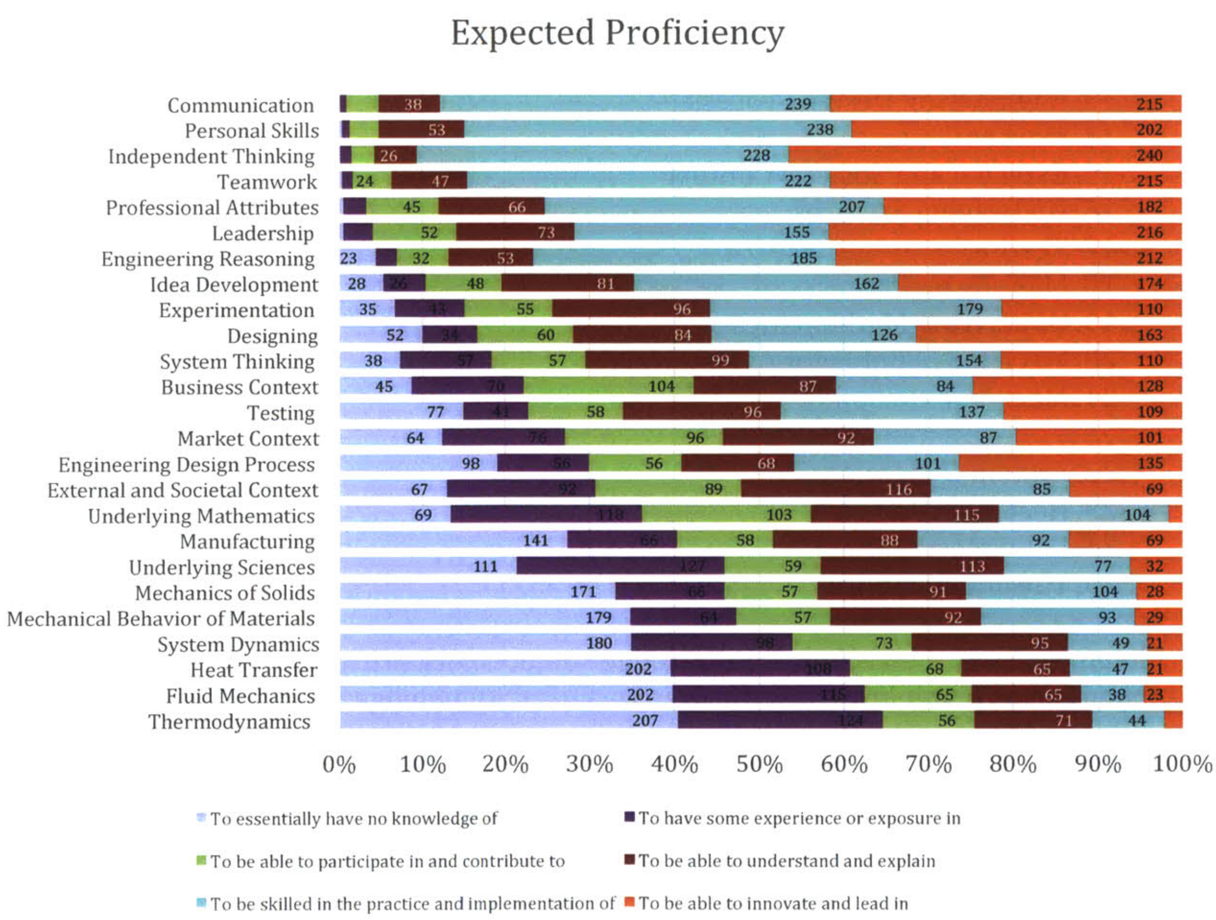


Figure 3: Expected Proficiency Bar Chart, sorted by most proficient to least proficient.

Comparing the Frequency of Use and the Expected Proficiency graphs, a high Frequency correlates to a high Expected Proficiency, as one would expect. Quantitatively, the two scales are difficult to compare, since the frequency scale is not linearly distributed while the proficiency scale has a more linear interval. Qualitatively, however, the four groupings listed above in the frequency discussion remain intact. The order within the groupings changes slightly, but does not differ by more than four slots (again, Testing having the largest jump between proficiency and frequency). In the Testing case, this larger gap can be justified because those using the skill once a month should still be able to participate and contribute to the process.

Due to this high correlation between the frequency of use and the expected proficiency, the graphs in the following section will focus on the frequency of use in more detail, using the assumption that the same analysis could be done of proficiency with similar results.

It may be discouraging to see the technical knowledge on the lower half of both the frequency and proficiency charts, however, these topics still form the foundation of a lot of engineering work. Looking at the bottom four topics, which remain in the same order in both the charts, around 18-30% use the skill at least once a month. However, about 35-46% need to at least be able to participate and contribute in this area of expertise. Overall, the technical knowledge and skills tend to be considered valuable to a specialized group of people, whereas the work environment skills are more career-independent.

<u>Sources of Knowledge and Skills</u>

The primary source graph was produced using the same method as the Frequency of Use and the Expected Proficiency charts. The left hand column's order is identical to the Frequency of Use graph, since the conditional logic of this question was based on the frequency response. Note that because of the conditional logic added to the question, the total number of responses for each question varies significantly between topics.

The majority of the technical knowledge and skills were learned in large part in the undergraduate MIT curriculum. With the exception of *Manufacturing*, all of the Technical Knowledge topics had "Undergraduate Program at MIT" selected as the primary source more than 50% of the time. In the Engineering Skills block, all topics selected "Undergraduate Program at MIT" as their primary source at least 40% of the time. The five most frequently used skills, *Personal Skills, Independent Thinking, Professional Attributes, Communication*, and *Teamwork*, were largely learned in either a previous work experience or elsewhere. Interestingly, less than 50% of the primary sources for these five skills were learned in a formal learning environment—the Undergraduate Program at MIT (shown in light blue), Graduate Program (orange), or a Company-Sponsored Training Program (gray).

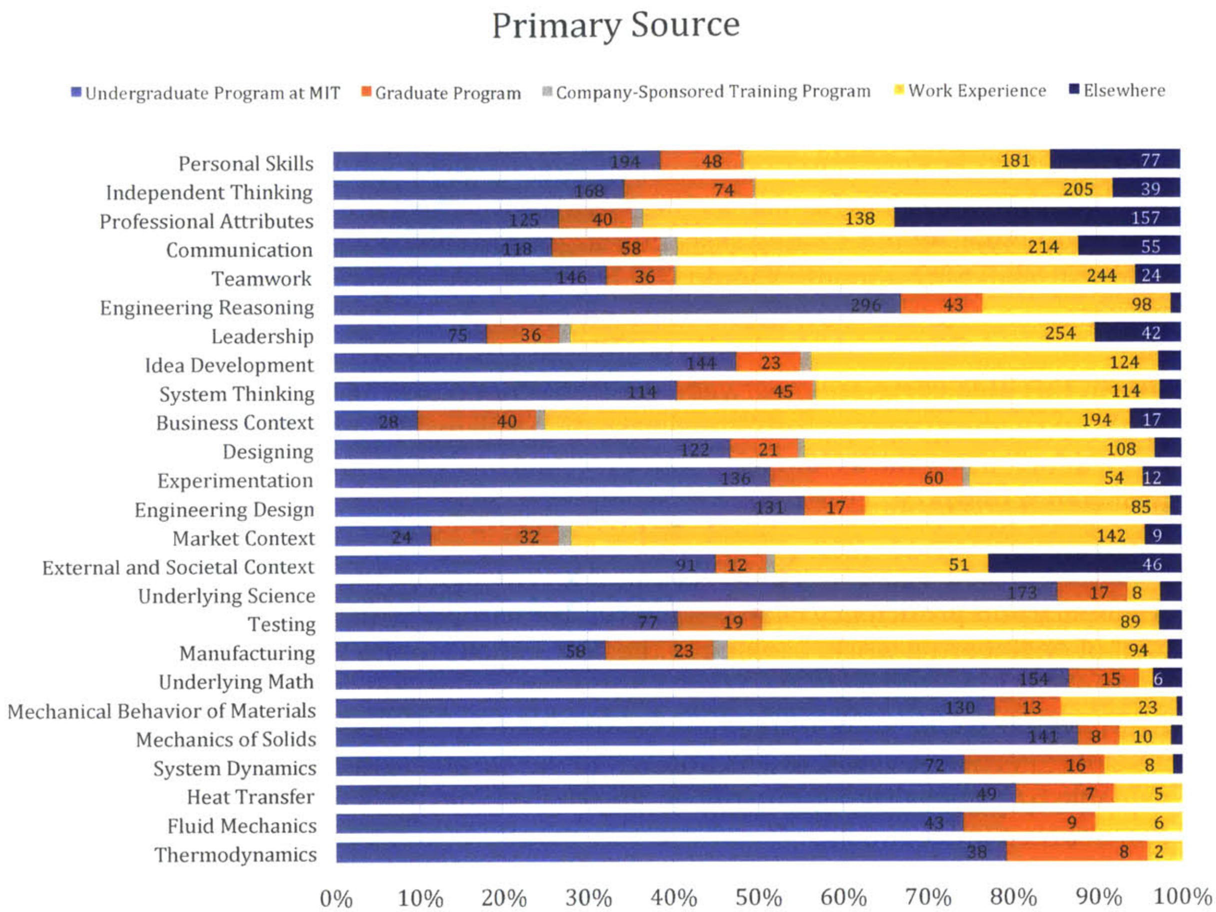


Figure 4: Primary Source Bar Chart, sorted by most frequently used to least frequently used.

It can be noted that there is a large proportion of responses that stated "Elsewhere" as their primary source of knowledge for both *Professional Attributes* and *External and Societal Context*. This could imply that there was some ambiguity in these topics, as the description of *Professional Attributes* includes "Ethics; Integrity; Continuous Learning" which could be hard to identify a primary source. Similarly, *External and Societal Context* was described as "Responsibilities of Engineers on Society; Global Perspective", which again might be difficult to identify a source for. In an effort to keep these answers succinct, there was no textbox included in this question. For future studies, this may be something to consider adding in order to receive a more descriptive response.

Adding the secondary sources into the tally, the next chart is generated. Since it was emphasized that a secondary source of knowledge should only be selected if applicable, the variation in responses is even larger than the primary source plot. About 69.6% of respondents selected a secondary source, with a standard deviation of 6.7%.

With the inclusion of the secondary sources, the number of "Company-Sponsored Training Program" responses tripled in size for all of the topics. As company-sponsored training programs tend to be short-term classes tailored to teach a specific task relevant to the individuals' area of work, it makes sense that these programs are effective in teaching a skill. However due to its short duration, it may not necessarily be considered a primary source, therefore the relative spike in secondary source selection is understandable. This can be particularly seen in *Leadership* and the five most frequently used skills, as well as *Business Context* and *Market Context*—skills that are used frequently in the workplace, therefore companies target them for sponsored training programs.

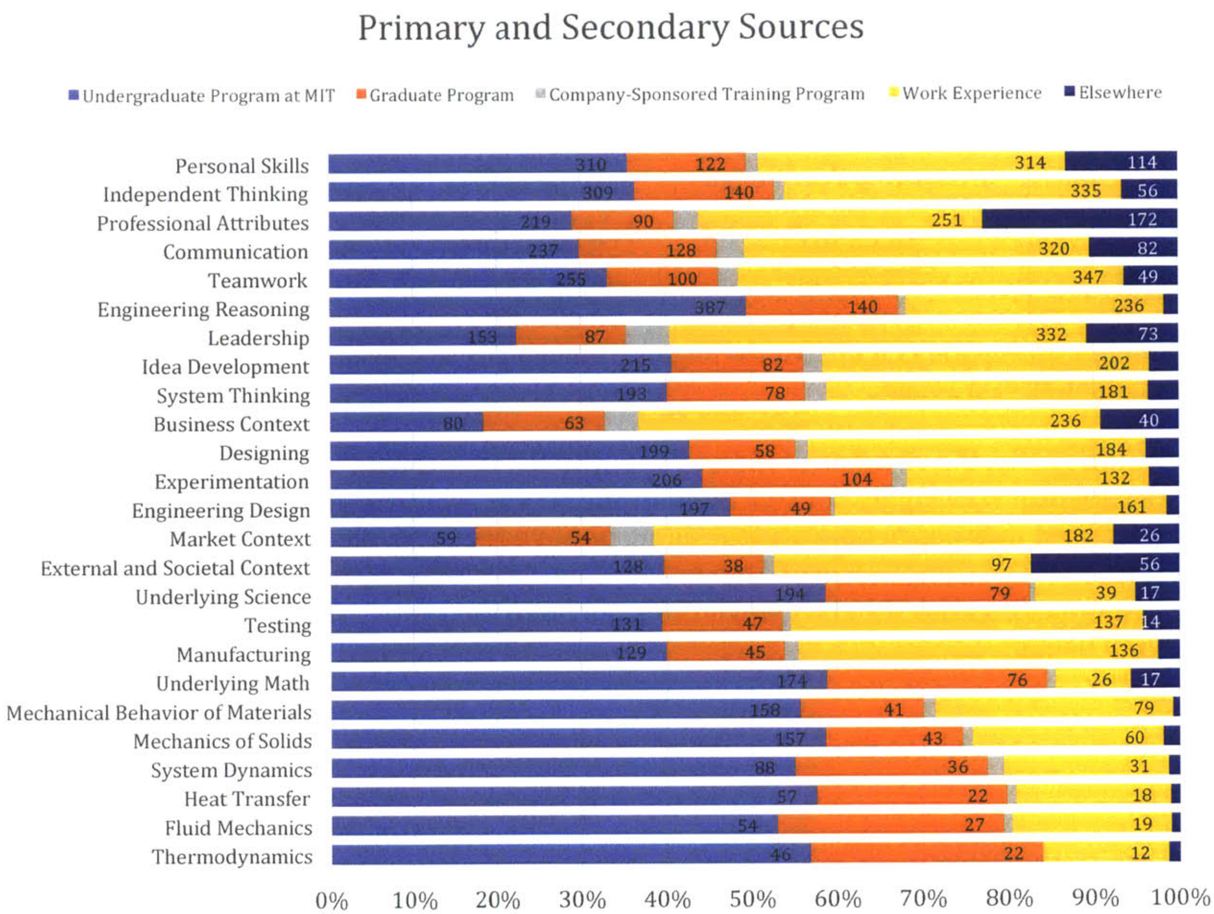


Figure 5: Primary and Secondary Sources Bar Chart, sorted by most frequently used to least frequently used.

Looking at the Technical Knowledge section, the percentage of both graduate program-based knowledge and work experience-based knowledge increased significantly, again with the exception of *Manufacturing* (where the percentage of undergraduate program-based knowledge increased instead of decreased). This could be an indication of continuous learning, with *Underlying Science, Underlying*

Math, and *Mechanics of Solids* seeing the largest changes (approximately a 27% decrease in undergraduate program-based knowledge).

However, it is still the case that several categories are still largely learned in an informal learning environment or elsewhere. These categories include *Professional Attributes, Communication, Teamwork, Leadership, Business Context*, and *Market Context*.

Occupation Comparisons

With all of the data from the survey, there are countless ways to look at the dataset in more detail. First I chose to look at the distribution of occupations. By graduating year, as the number of years since graduation increases the percentage of engineers generally decreases and the percentage of managers tends to increase, in agreement with Catherine Kelly's conclusion. The values below are given with a 95% confidence interval.

Year Group	Graduating Year Range	% of Engineers	% of Managers	% of Engineers and Managers
1	2009-2013	52.83 ± 8.9%	8.8 ± 6.0%	61.63%
2	2003-2007	35.29 ± 4.5%	19.2 ± 6.9%	54.49%
3	1992-1996	18.49 ± 8.9%	30.3 ± 8.4%	48.79%

Table 1: Occupation Comparisons- Engineers and Managers. Average taken over each graduating year range.

Additionally, the number of individuals who listed "Student" as their current occupation was highly concentrated in the recent graduate years. To see what advanced degrees people are pursuing, or have received, please refer to Appendix 9. Note that the sample size of each graduating class is small (ranging from 22 to 72 responses), so the standard deviations between the years will typically be higher than usual.

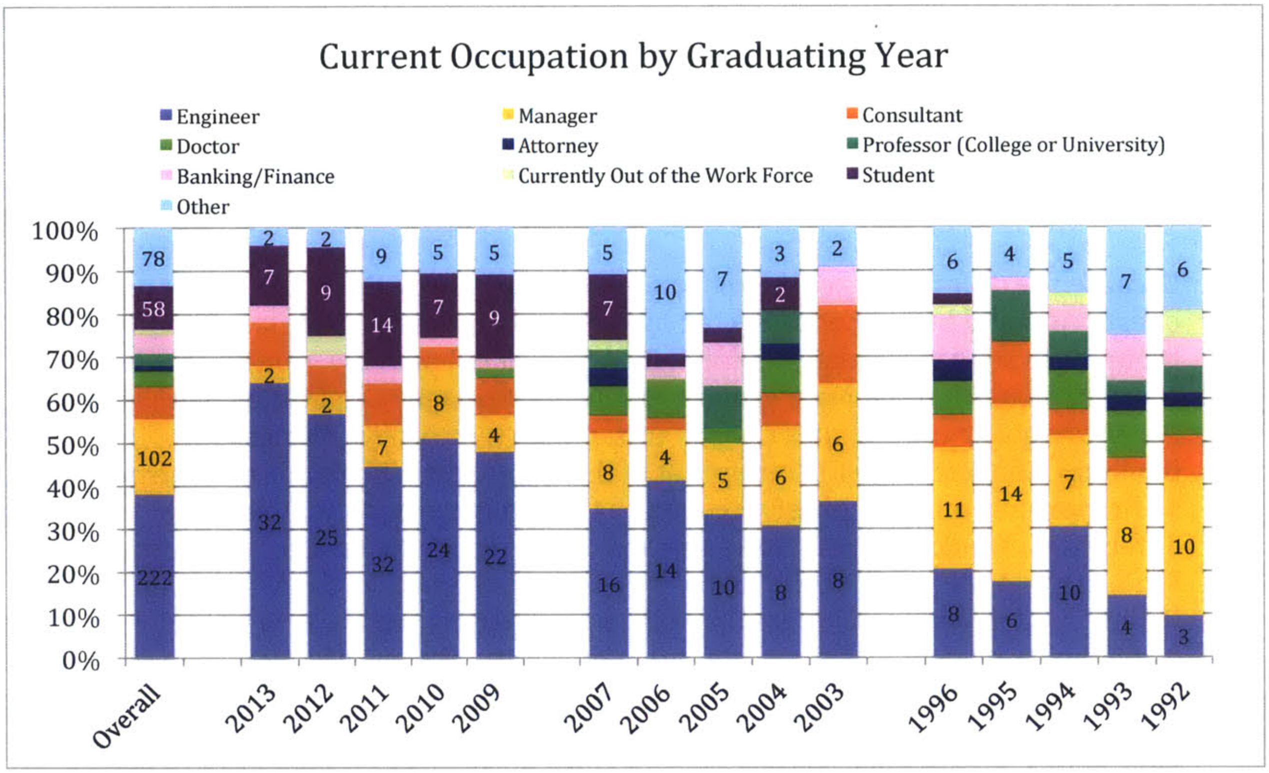


Figure 6: Current Occupation by Graduating Year.

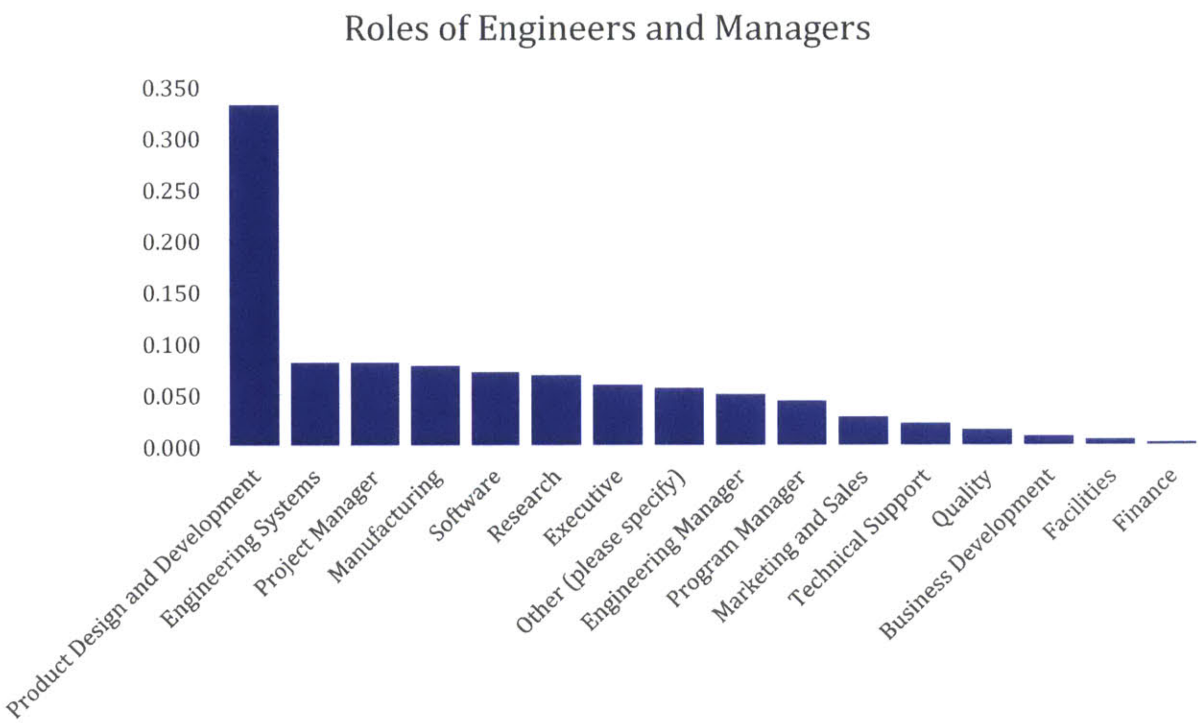


Figure 7: Roles of Engineers and Managers.

Within the group of people who selected Engineer or Manager, the distribution of role was as follows: Product Design and Development, Engineering Systems, Project Manager, Manufacturing, Software, Research, Executive, etc. The distribution is fairly even, with the exception of Product Design and Development.

The number of individuals who self-reported as "Other" is relatively high. These responses included, but were not limited to, Business Development, Real Estate, Small Business Owner, Military, and High School Teacher.

Because the occupations of the respondents were known, the frequency of use questions could be further dissected by career. In order to create large enough group sizes so that the analysis could be extrapolated onto the group as a whole, I chose to focus on three main groups: Engineers, Managers, and Other. Note that this Other category now includes Consultants, Doctors, Attorneys, Professors, Banking/Finance, those Currently Out of the Work Force, Students, and the original self-reported Others. In order to compare these three groups and plot the differences, I took the mean and standard deviations of the Frequency question in SPSS, mapping "0" to "Never", "1" to "A Few Times a Year, "2" to "At Least Once a Month", and so on. As mentioned before, since the time scale was in no way linearly distributed, the averages themselves do not represent anything. However, they do provide a straightforward method of comparison between the three groups. In the Technical Knowledge block engineers tend to use the topics more frequently than managers, while in the Professional Attributes block managers tend to use the topics more frequently than engineers. However, both engineers and managers use the skills in the Engineering Skills block similarly. There are notable large differences in *Leadership, Communication, Business Context,* and *Market Context,* with managers using the skill much more frequently than engineers.

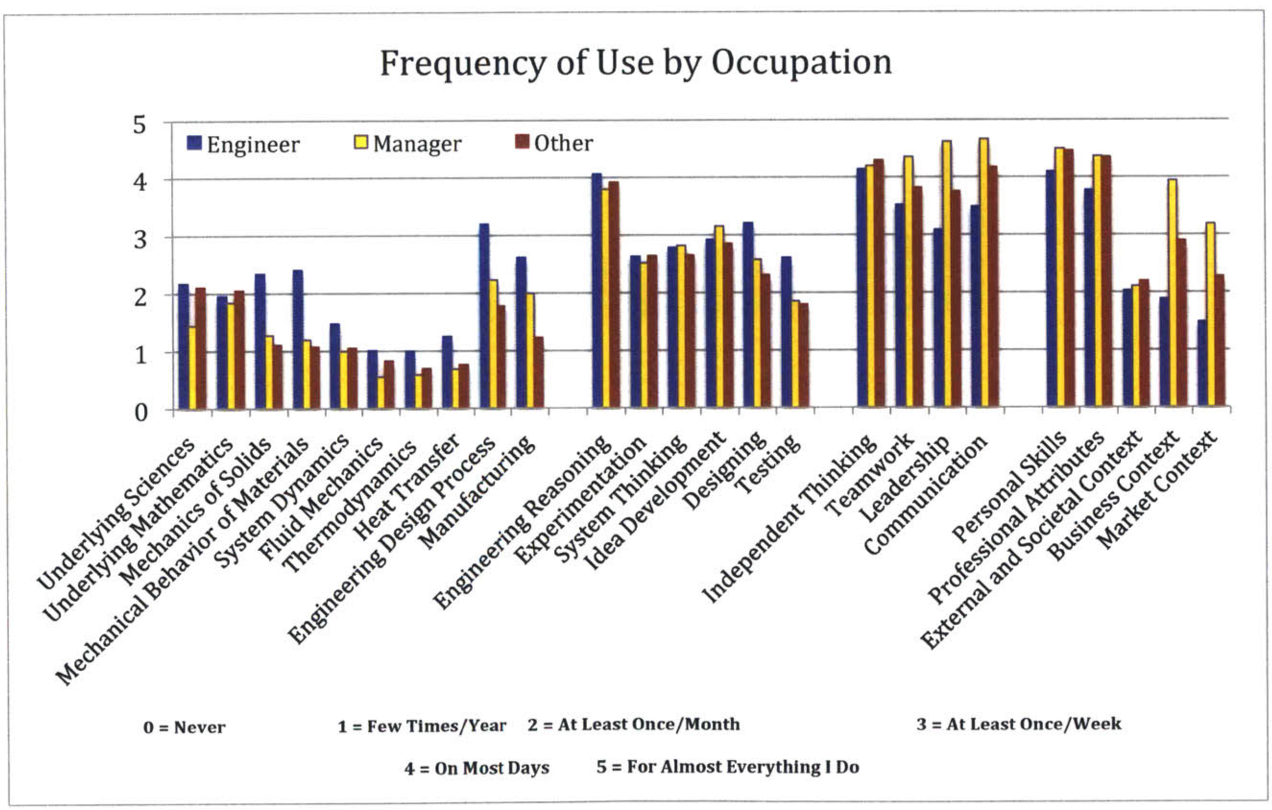
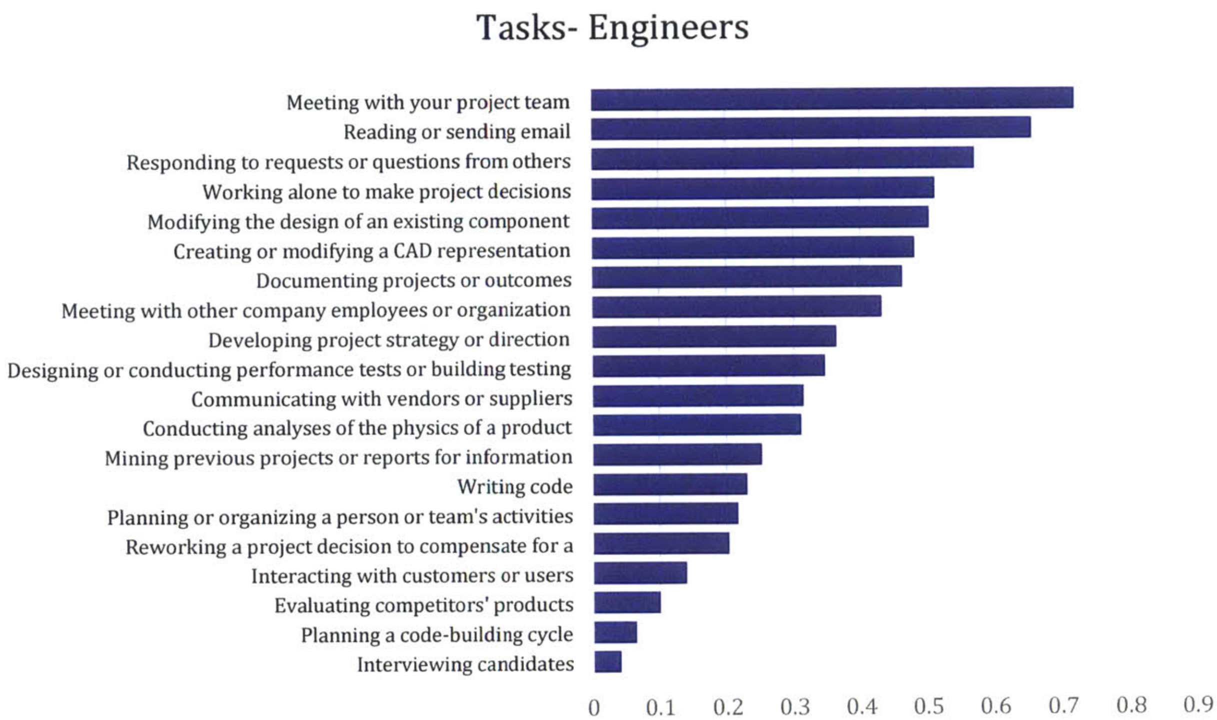
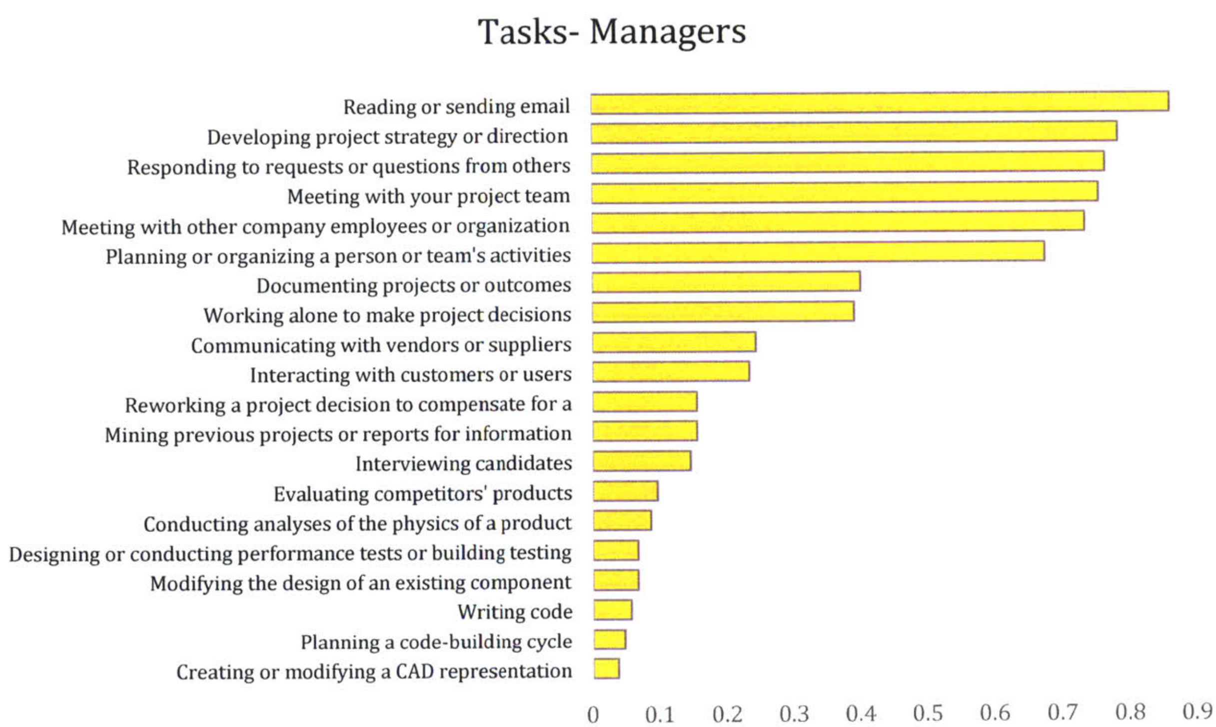


Figure 8: Frequency of Use by Occupation.

In the survey, individuals were asked to select all of the tasks that they spent more than five hours on during the previous week. Splitting the responses up by the three occupation groups and then arranging the tasks by the most frequently selected, the following graphs were produced.





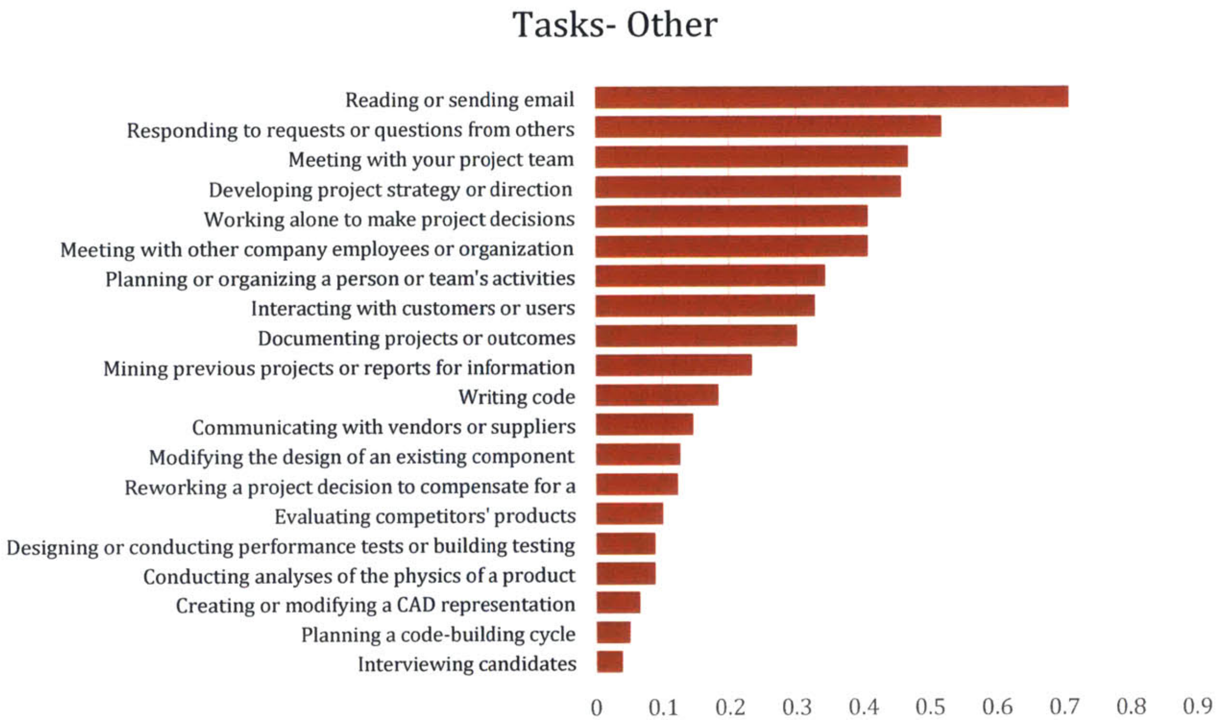


Figure 9: Tasks: Engineers, Managers, and Other. Sorted by most frequently selected response.

Below is a compilation of the task rankings into a table, to better compare the typical tasks of engineers, managers, and 'other'. *Communicating and Interacting* tasks are underlined and orange, *Planning and Designing* tasks are *italicized and green*, and *Creating and Modifying* tasks are in purple.

Engineers	Managers	Other
Meeting with one or more members of your project team	Reading or sending email	Reading or sending email
Reading or sending email	*Developing project strategy or direction*	Responding to requests or questions from others
Responding to requests or questions from others	Responding to requests or questions from others	Meeting with one or more members of your project team
Working alone to make project decisions	Meeting with one or more members of your project team	*Developing project strategy or direction*
Modifying the design of an existing component	Meeting with other company employees or organization members	Meeting with other company employees or organization members
Creating or modifying a CAD representation	Planning or organizing a person or team's activities	*Working alone to make project decisions*
Documenting projects or outcomes	*Documenting projects or outcomes*	Planning or organizing a person or team's activities
Meeting with other company employees or organization members	*Working alone to make project decisions*	Interacting with customers or users
Developing project strategy or direction	Communicating with vendors or suppliers	*Documenting projects or outcomes*
Designing or conducting performance tests or building testing rigs	Interacting with customers or users	*Mining previous projects or reports for information*
Communicating with vendors or suppliers	*Mining previous projects or reports for information*	Writing code
Conducting analyses of the physics of a product	Reworking a project decision to compensate for a misunderstanding	Communicating with vendors or suppliers
Mining previous projects or reports for information	Interviewing candidates	Modifying the design of an existing component
Writing code	*Evaluating competitors' products*	Reworking a project decision to compensate for a misunderstanding
Planning or organizing a person or team's activities	Conducting analyses of the physics of a product	*Evaluating competitors' products*
Reworking a project decision to compensate for a misunderstanding	Modifying the design of an existing component	Conducting analyses of the physics of a product
Interacting with customers or users	Designing or conducting performance tests or building testing rigs	Designing or conducting performance tests or building testing rigs
Evaluating competitors' products	Writing code	*Creating or modifying a CAD representation*
Planning a code-building cycle	*Planning a code-building cycle*	*Planning a code-building cycle*
Interviewing candidates	*Creating or modifying a CAD representation*	Interviewing candidates

Table 2: Tasks: Engineers, Managers, and Other. *Communicating and Interacting* tasks are underlined and orange, *Planning and Designing* tasks are *italicized and green*, and *Creating and Modifying* tasks are in purple.

Career Paths

An area of high interest is the correlation of career-related questions based on graduating year. In the survey, people were asked to select their first occupation after graduating with a Bachelor of Science from MIT. They were given the additional option to select "Same as current occupation", seen in green. As the number of years since graduation increases, the number of people who currently have the same occupation that they did immediately after college slowly diminishes. A significant portion of alumni switch careers as they get older, either through managerial promotions or intentional career changes.

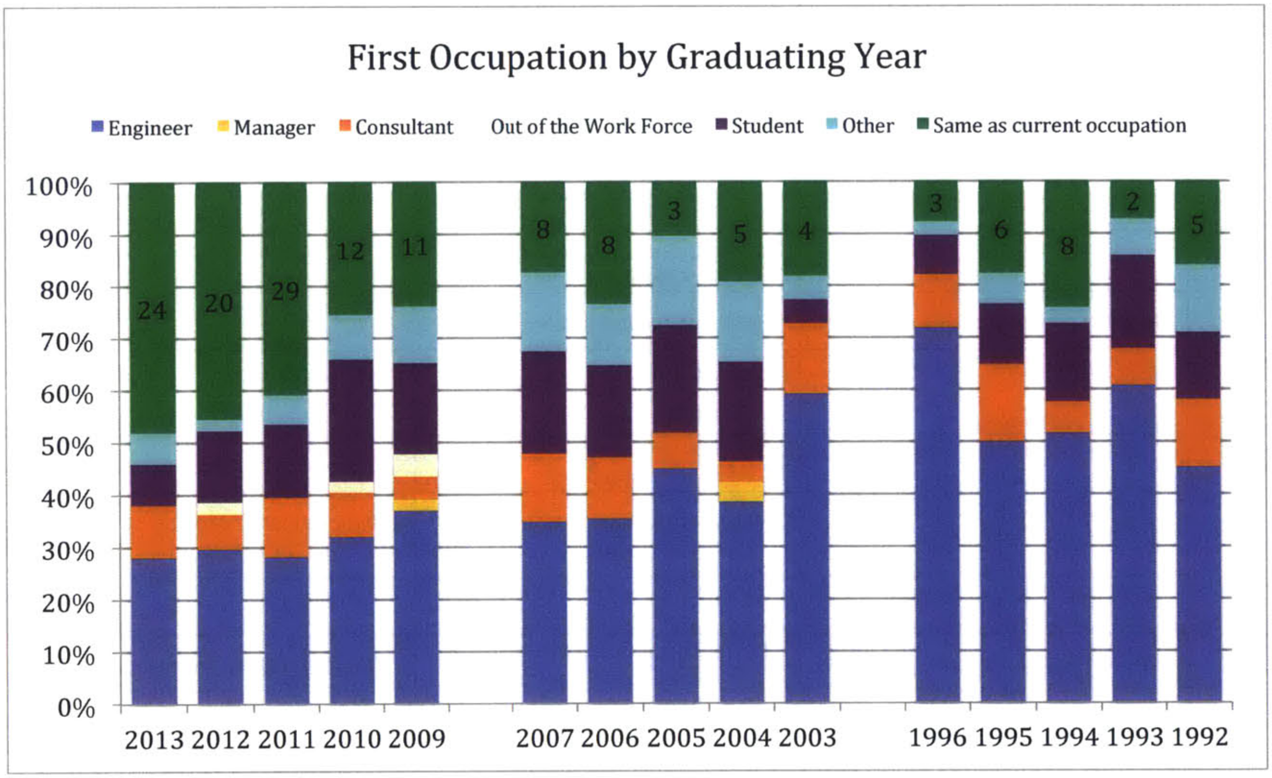


Figure 10: First Occupation by Graduating Year.

Using the *Transform* function in SPSS, the value of this question was recoded if the person responded with "Same as current occupation". This was done so that we could directly compare the types of jobs that people took directly out of college with the types of jobs that people currently have. The following graph was produced using the recoded values.

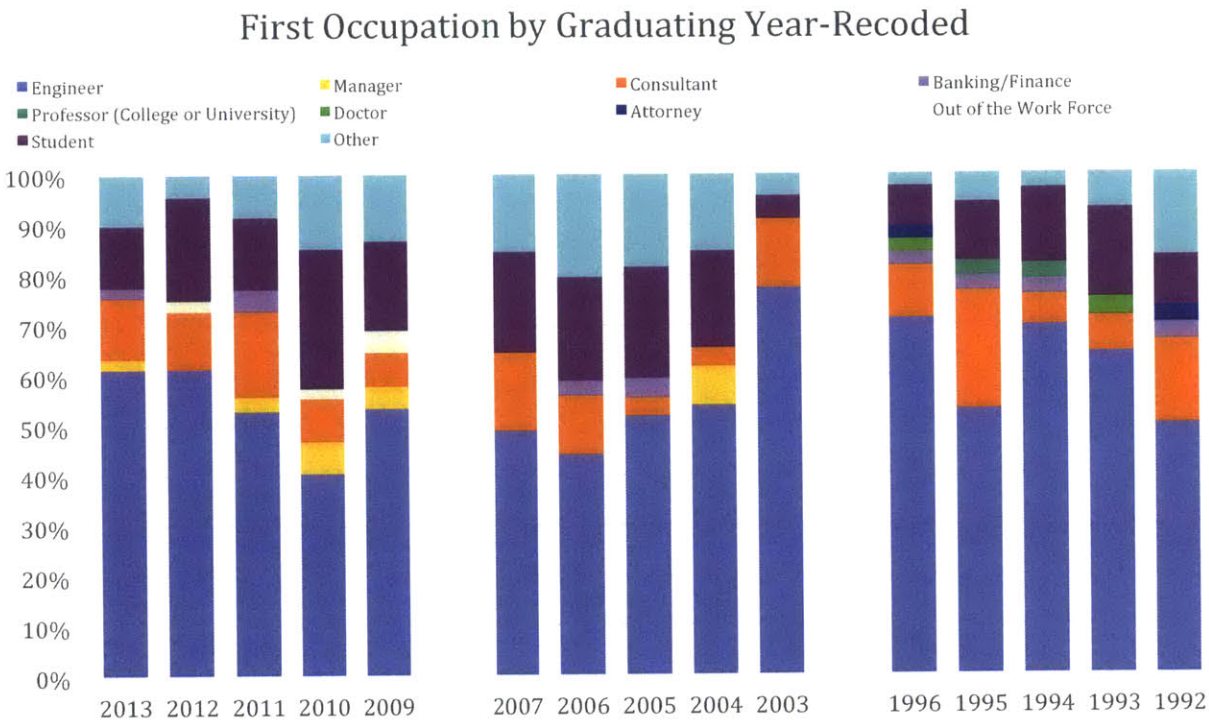


Figure 11: First Occupation by Graduating Year-Recoded. The responses in green above (Figure 10) were recoded to the individual's current occupation.

Two direct career path-related questions were asked in the survey:

1. How many different companies have you been employed at full-time since you received your Bachelor of Science from MIT?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6-8
   g. 9-12
   h. 12+
2. How many years have you worked at your current place of employment?
   a. <1 year
   b. 1 year
   c. 2 years
   d. 3 years
   e. 4 years
   f. 5 years
   g. 6-7 years
   h. 8-10 years
   i. 11-15 years
   j. 16-20 years
   k. 20+ years

The following boxplot charts were taken directly from SPSS, separated by graduating year. The values for the range responses were calculated using the mean. For the singular *12+ companies* response, the value of 13 was assigned. In this boxplot, the bolded line represents the median response value, the shaded box represents the 25th to 75th percentile, and the vertical lines represent the minimum and maximum values. The outliers are represented with circles and stars. Plotted as a function of the number of years out of college, the following plot is obtained.

How many different companies have you been employed at full-time since you received your Bachelor of Science from MIT?

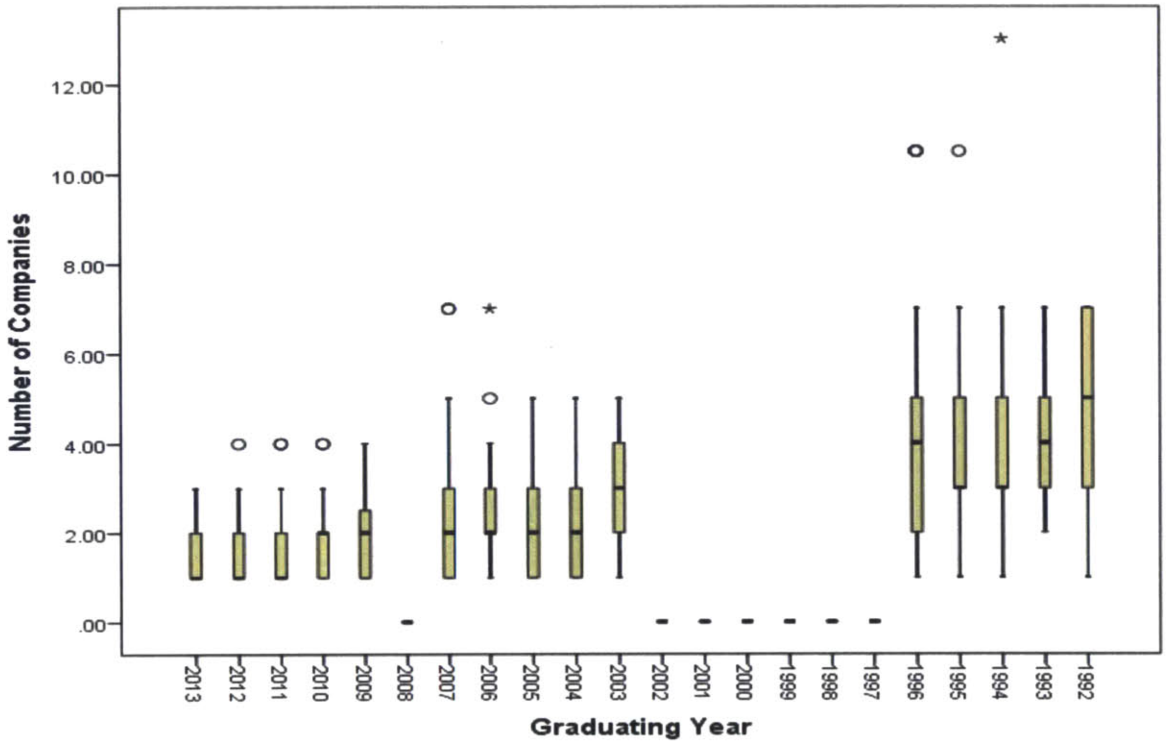


Figure 12: Number of Companies by Graduating Year. The bolded line represents the median value, the shaded box represents the 25th to 75th percentile, and the vertical lines represent the minimum and maximum values. The outliers are represented with circles and stars.

The values for the range responses were calculated using the mean. For the singular *12+ companies* response, the value of 13 was assigned. In this boxplot, the bolded line represents the median response value, the shaded box represents the 25th to 75th percentile, and the vertical lines represent the minimum and maximum values. The outliers are represented with circles and stars. Plotted as a function of the number of years out of college, the following plot is obtained.

How many years have you worked at your current place of employment?

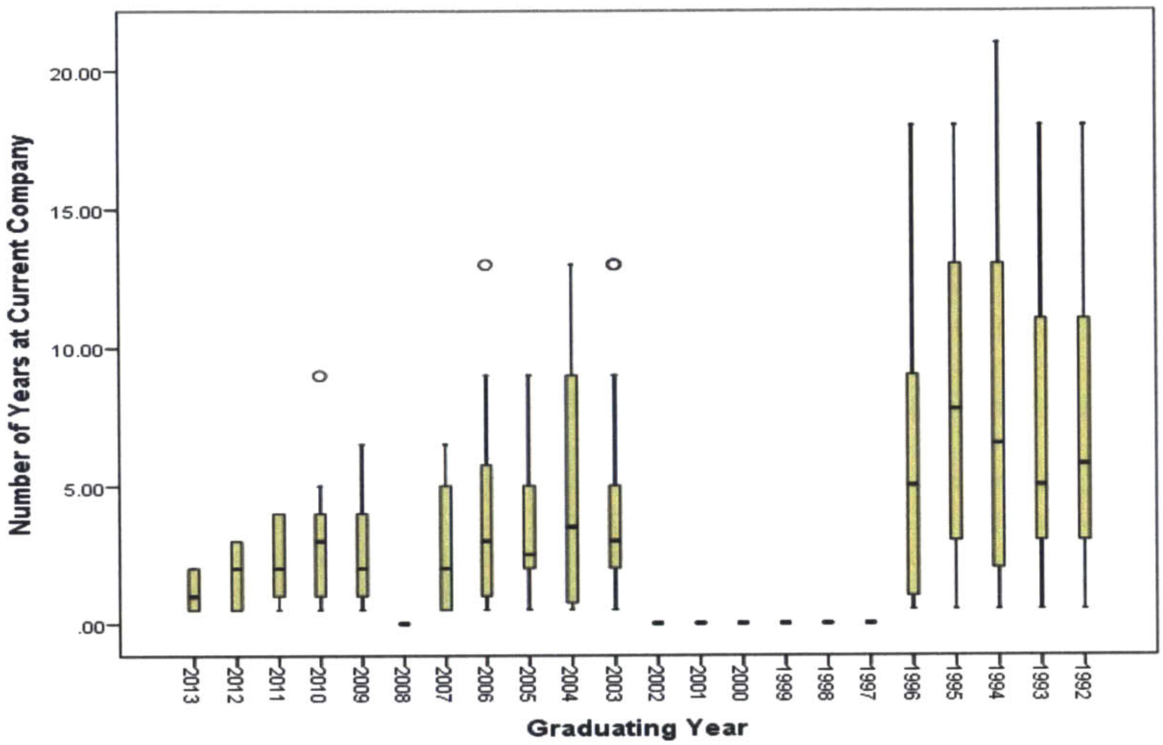


Figure 13: Number of Years at Current Company by Graduating Year. The bolded line represents the median value, the shaded box represents the 25th to 75th percentile, and the vertical lines represent the minimum and maximum values. The outliers are represented with circles and stars.

Again, the values for the range responses were calculated using the mean. For the *20+ years* responses, the value of 21 was assigned. Plotted as a function of the number of years out of college, the above plot is obtained.

Due to the small sample size, the deviations in these averages are larger than expected. With more data points, these deviations can be improved significantly.

Chapter 4: Data Interpretations and Implications

Data Interpretation

Through this survey's results, I believe that we can conclude areas of strength and areas for improvement for the Mechanical Engineering curriculum. Again, I include my personal opinions on the interpretation of the data with the complete understanding that I am not an expert in the curriculum details aside from my personal experience as a student.

In accordance with what Kristen concluded in her 2004 thesis, I believe that the MIT curriculum does a great job with providing a solid foundation of technical knowledge reasoning, as seen in the source tables. Furthermore, this solid foundation is necessary for the types of careers that MIT alumni pursue, as seen in the frequency and proficiency correlations—despite the fact that the technical knowledge topics are least frequently used, alumni are still expected to be comfortable with and able to contribute to the topic.

I also agree that from the implications of the frequency and primary source charts, there is room for improvement in the topics pertaining to the work environment and one's personal and professional skills. However, since the most effective way to learn these skills stem from an informal learning environment such as work experience, these skills cannot—and should not—be taught directly in classes. Instead, they must be incorporated into the already existing course load. The lecture-based style of the core technical classes, specifically 2.001-2.006, does not address these skills, and therefore has the potential for integration.

Yet, I do believe that MIT's strength in teaching engineering reasoning and problem solving also arises from the lecture-based style of the core technical classes. As many people stated in the first open-ended question, problem solving and critical thinking were huge takeaways from the undergraduate course load. Of the responses received, at least 102 people mentioned the problem solving skills learned from MIT, and 73 mentioned learning how to think critically and/or analytically. It should not go unnoticed that these are also incredibly valuable skills that cannot be taught directly in classes, therefore MIT has been very successful in this incorporation into the curriculum.

According to the alumni, project-based classes (2.007-2.009) are particularly strong classes. In the same open-ended question as above, at least 21 responses specifically mentioned 2.007, 17 mentioned 2.008 and 70 mentioned 2.009 as being valuable learning experiences. In the responses, these project-based classes effectively taught important skills such as hands-on experience, teamwork, and leadership.

Class Mentioned	**# of Times Mentioned**	**Specific Skills/Knowledge Learned**
Core Classes (GIRs, 2.001-2.006)	14	Technical Knowledge, Analytical Thinking/Problem Solving
2.007	21	Prototyping, Hands-on Experience
2.008	17	Teamwork, Hands-on Experience
2.009	70	Teamwork, Design, Leadership
2.671	7	Documentation, Communication

Table 3: Open-ended Response Frequencies.

<u>Implications on the Curriculum</u>

There is a delicate balance of both the more rigid lecture-based structure and the looser project-based classes, since both effectively teach very applicable, yet different, skills. In order for the current curriculum to address the topics related to work environment and one's personal and professional skills, I believe that the best approach is not necessarily to modify the teaching style of the core technical classes, 2.001-2.006, but instead to balance out the number of lecture-based classes and project-based classes.

To my knowledge, this is the one of the objectives for the new 2-A curriculum, where students can choose shorter lecture-based technical classes so that they can pursue classes in their specific interests. I agree that a similar modification should be made to the *Course 2* curriculum—not to the same extent, but to an extent. Similar to the old 2-A requirements, I think a possible approach would be to make one of the technical second-level subjects (2.002, 2.004, 2.006) optional, thereby creating space to add another required project-focused class. A detailed list of the old 2-A requirements can be found in Appendix 10. Contrary to the old 2-A curriculum, I believe that 2.008 should remain a required class, with some modifications. Thoughts for this new project-focused class will be discussed later.

<u>Curriculum Modifications and Additions: A Personal Opinion</u>
In a slightly modified Primary Source chart, where the Elsewhere option is completely removed for ambiguity purposes, there are six topics that stand out as having surprisingly low undergraduate contributions:

- Manufacturing
- Teamwork
- Business Context
- Market Context
- Communication
- Leadership

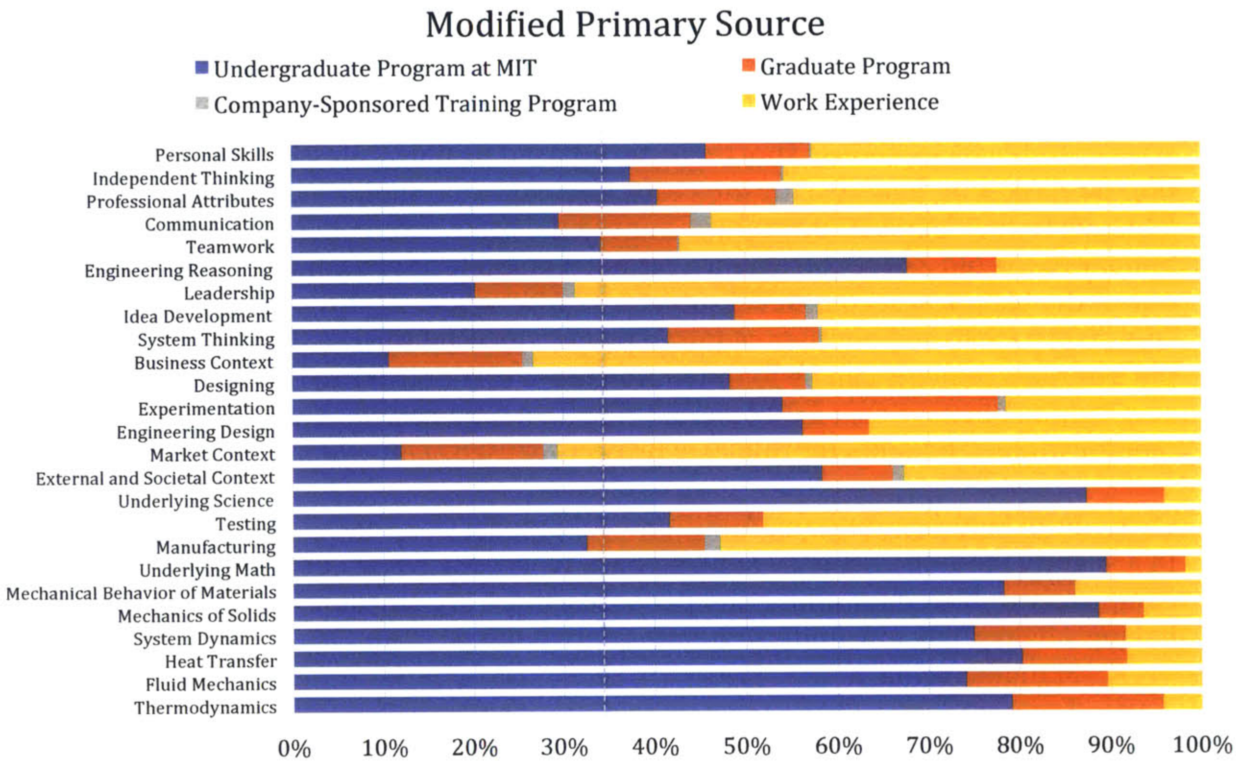


Figure 14: Modified Primary Source Bar Chart, where the *Elsewhere* responses were taken out.

All of these topics have something in common—of the alumni who use these skills more than once a week, less than 35% of them cite MIT's undergraduate program as their primary source.

The first two topics, *Manufacturing* and *Teamwork,* are two main learning objectives of 2.008.

From a reflection of my personal experience as a *Course 2* undergraduate, I have noticed certain strengths that I think could be applied further to other aspects of the curriculum in order to progress. Firstly, I believe I have been very fortunate because I have consistently had passionate and committed professors for the majority of my core classes. Specifically, there are four classes that stand out, and I think they all possess one key characteristic. These classes are:

- Measurement and Instrumentation (2.671)
- The Product Engineering Process (2.009)
- Physics I & II (8.01 & 8.02).

The key feature that I have observed is the continuity of faculty throughout the years (again, to the extent of my knowledge). Having one consistent faculty member teach the course ensures that the feedback given at the end of every semester is seriously taken into consideration for the future semesters. Additionally, this continuity of faculty members implies a high personal investment in the quality of how the class is taught, which is incredibly useful for that class's development. Please note that this is a one-way implication, and that there are numerous cases where a faculty member invests a huge portion of their time to the improvement of a class without teaching the class every semester.

I understand that for the technical core classes, the continuity of professors may be difficult since they tend to have their own research on the side (again, this is a one-way generalization) and that it may be more difficult since 2.008 is taught every semester. However, I believe that this feature could be feasibly applied to the 2.008 class structure with positive benefits.

Another interesting area of discussion would be to consider the integration of the TEAL-style into the 2.008 class structure. The TEAL-style, which is used to teach 8.01 and 8.02, could potentially help increase the incorporation of teamwork and communication.

With regard to my thoughts on a new required project-focused class, I believe that this is the opportunity to add the topics of *Business Context* and *Market Context* directly into the curriculum. Seeing their extremely low undergraduate numbers in the Primary Source chart, I believe that they have great potential in the course load. Between 40-50% of survey respondents use this knowledge on a weekly basis. It can be seen that managers use these topics significantly more than engineers, however, by their early 30s approximately 20% of MIT alumni become managers. This fraction, seen in the previous table on page 16, increases to 30% by the early 40s—a significant portion of our alumni. This project-based class would most likely indirectly incorporate the skills of *Leadership, Teamwork,* and *Communication*, thereby addressing the rest of the topics where the undergraduate learning contribution is noticeably low.

Through the responses received from this survey, it is clear that the Mechanical Engineering department has effectively taught the skills that they focus on. I believe that a slightly more balanced focus on both communication and technical skills would be beneficial to graduates in their professional lives.

Future Steps

Due to time constraints and the multitude of data, there are several areas that did not get covered but I think would benefit from further research. First and foremost, with the third wave of additional responses after the second reminder was sent out, the graphs above should all be reproduced with the entire dataset after the survey is closed. Quick comparisons were made to confirm that nothing was significantly changed with the new response set; therefore the above analysis is still valid. However additional responses will significantly help with the small sample issue that occurs in data analysis of the *Career Path* section.

In terms of data comparison, I believe that a huge area of interest would be to delve into the consistency between the 2004 survey responses and the 2015 responses. The only categories that are directly comparable are the Frequency of Use and Expected Proficiency questions, with the exception of the *Dynamics* and *Leadership* topics, but the comparison of the two datasets would be extremely insightful. There are two main comparisons that can be made:

1. A comparison of the 2004 responses with the middle year group (graduating classes of 2003-2007) in order to look at alumni who are the equivalent age group
2. A comparison of the 2004 responses with the third year group (graduating classes of 1992-1996) in order to look at alumni who responded to both surveys

There are also additional topics that I would have liked to investigate in the *Occupation Comparison* section, but did not. One comparison I would have liked to spend more time on is the number of companies that people have worked at relative to the type of occupation they hold. I believe that this can tell a lot about the stability of a job type: whether a specific occupation tends to be associated with frequent company changes, etc. It is often said that consultants spend 2-5 years before switching either their career or their place of employment. With the number of responses who reported as consultants, this could be researched using data.

Another topic of interest in the *Occupation Comparison* section would be the re-categorization of occupation by technical focus. I did not discuss the results of the engineering, management, and consulting roles asked in the survey, but this could easily add another level of analysis to Chapter 3. Finally, for a more accurate representation of the data, it is recommended to do a manual re-categorization of the self-reported "others" into the pre-sorted categories. Going through the list of "other" descriptions, there were several people who identify as project managers and product managers, which could have been added to the *Manager* category. There are also several responses for Business Development, Real Estate, High School Teacher, and Military, which could have been added as their own group. However, this has a relatively small impact since the *Other* category was combined during analysis.

Conclusion

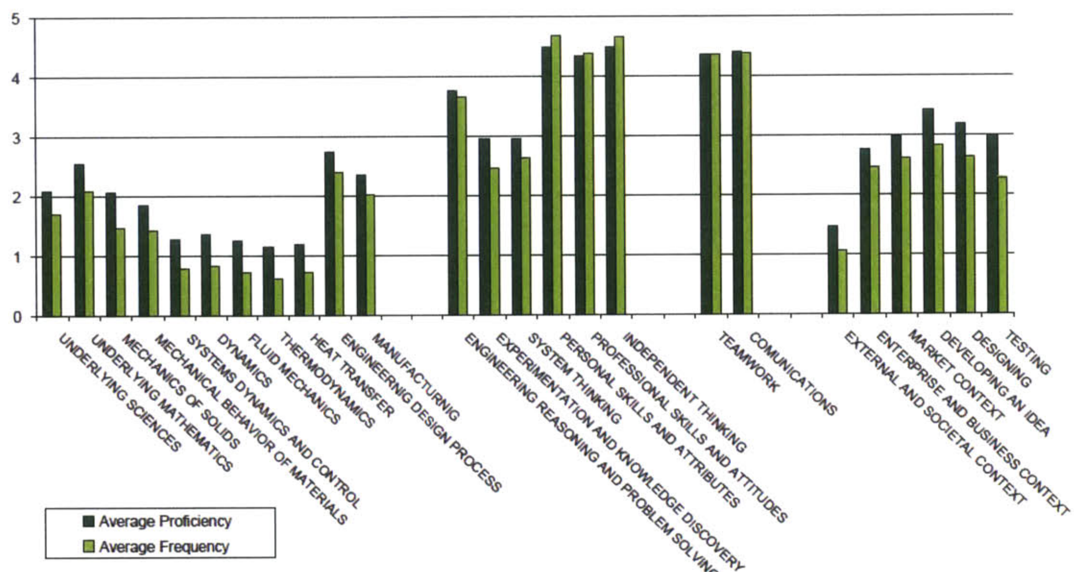
The Mechanical Engineering Department has been actively refining their programs in order to best suit the needs of their students, as seen by the recently remodeled 2-A curriculum. As such, I believe that there is much discussion about suggested improvements to the original Course 2 curriculum, and my research is only a small portion of the efforts going into this topic. I am sure that there is much debate about potential changes, both in feasibility and in approach, and there may be many who disagree with some things that I have said. My hope is that the data I have found will encourage further discussion on the topic, as I know that the department is constantly looking for ways that they can improve the preparedness of their alumni to be successful in post-graduate life.

Appendices:

Appendix 1: Kristen Wolfe's Thesis

The figures below are taken directly from Kristen Wolfe's thesis, showing her results on Frequency of Use, Expected Proficiency, Source, and Occupation. The Frequency of Use and Expected Proficiency values were found using the average of all the responses.

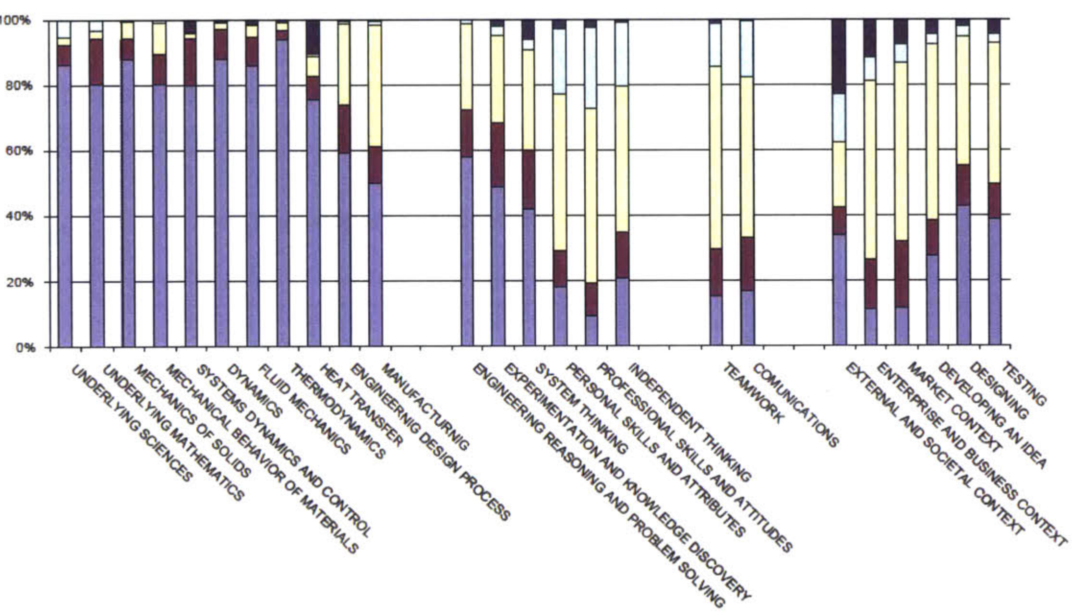
Mean Expected Proficiency and Frequency of Use



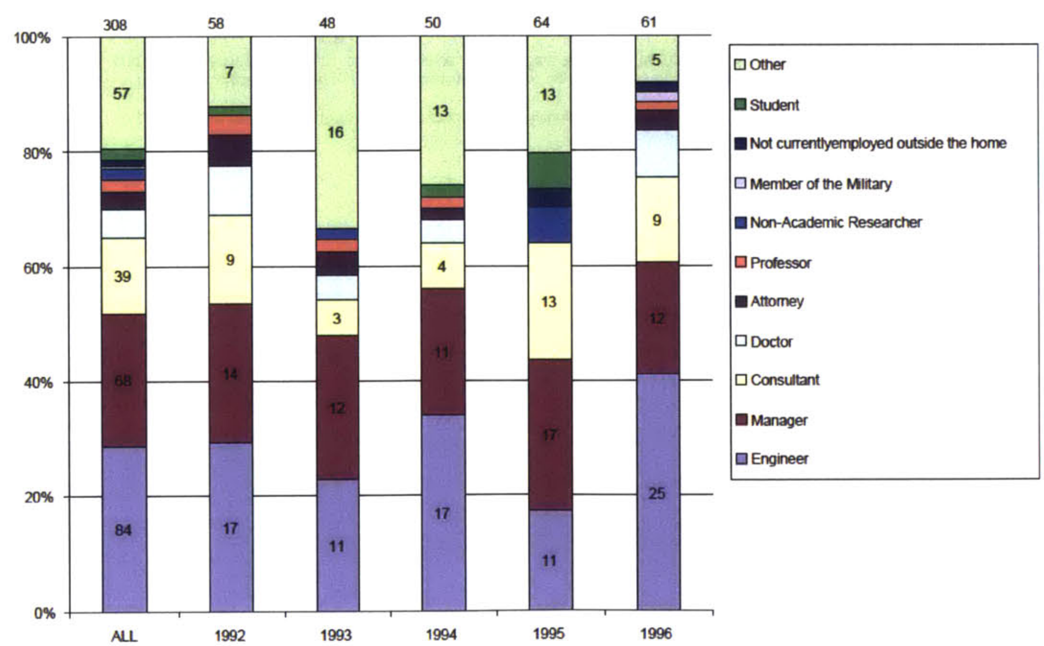
Expected Proficiency: 0 To have essentially no knowledge of, 1 To have experienced or been exposed to, 2 To be able to participate in and contribute to, 3 To be able to understand and explain, 4 To be skilled in the practice or implementation, 5 To be able to lead or innovate in.

Frequency of Use: 0 Never, 1 Hardly ever - a few times a year, 2 Occasionally - at least once a month, 3 Regularly - at least weekly, 4 Frequently - on most days, 5 Pervasively - for most everything I do

Source



Survey Respondents



Below is an excerpt from Kristen Wolfe's chapter on the interpretation of her data.

> Instead, I believe the charts show a need for integration of other topics into the existing core classes. My experiences in 2.001-6 have shown me that these classes are largely or entirely content knowledge based. The emphasis, from my viewpoint, is on knowing the material. I believe the department does a good job of providing the students with a very broad range of technical knowledge and reasoning. This is also evidenced on the source table with around 80% citing MIT as the primary source of their knowledge in these areas.
>
> One disconnect I see is in the area of engineering reasoning and problem solving. Only 60% report their primary source as MIT. I assume that most professors believe the problem sets they assign are addressing this area. However, I'm not sure that is what students get out of such an exercise. I believe that for students to effectively learn engineering reasoning and problem solving they must be directly taught how in the class. As Prof. Seering pointed out in a presentation to the Engineering Committee on Undergraduate Education, most Professors cannot verbalize their problem solving method [9]. Yet students are for the most part expected to figure it out on their own. I know from experience that some do not figure it out and only learn to recognize patterns in problems and map them onto other problems at test time. I believe this is an area that needs to be given serious attention if students are to be successful in a real world engineering environment.
>
> Another disconnect I see is in the area of experimentation and knowledge discovery. Less than 50% report their primary source as MIT. I assume that most professors believe the labs are addressing this area. However, I do not believe that students get this experience from the labs. The labs students are given in the various course 2 classes have explicit set-ups and desired outcomes. Students aren't so much discovering knowledge as they are following a prescribed set of instructions. Real experimentation is being given a problem or question and experimenting to discover the answer. It would be a challenging thing to replicate in the class environment, but perhaps the only way to give students the necessary background in experimentation and knowledge discovery.
>
> The largest disconnects are in the areas of personal skills, professional skills, independent thinking, teamwork and communication. These areas received the largest scores for proficiency and frequency and the lowest for learning at MIT.

Appendix 2: Kristen Wolfe's Survey

This section serves to show the order and format in which the questions were asked. The full list of topics is not shown in full in the screenshot of the survey, but a full list is provided in Chapter 2.

This survey enumerates various topics associated with engineering. Please rank each topic according to the following three criteria:

1. Expected Proficiency
   For people in your line of work and at the same stage as you are in your career (8 to 12 years past the BS degree), how competent are they expected to be in each of these areas? Please mark a number from 0-5 indicating the necessary proficiency level in column 1:
   0. To have essentially no knowledge of
   1. To have experienced or been exposed to
   2. To be able to participate in and contribute to
   3. To be able to understand and explain
   4. To be skilled in the practice or implementation of
   5. To be able to lead or innovate in

2. Frequency of Use
   In your present position, how frequently do you employ the knowledge and skills from each of these areas? Please mark a number from 0-5 indicating the frequency in column 2:
   0. Never
   1. Hardly ever – a few times a year
   2. Occasionally – at least once a month
   3. Regularly – at least weekly
   4. Frequently – on most days
   5. Pervasively – for most everything I do

3. Source of Your Knowledge
   Where did you gain the most understanding about each topic? Please mark a letter in column 3:
   U – Undergraduate Program at MIT
   G – Graduate School
   J – Job
   E – Somewhere Else
   N – Did Not Learn

Please indicate your response for each topic in each of the three columns.

If one or more of the italicized subtopics is of particular importance in your work, please circle it.
If we have missed a topic or a subtopic that is particularly important, please write it in.

1 TECHNICAL KNOWLEDGE AND REASONING	Proficiency 0-5	Frequency 0-5	Source U,G,J,E,N
1.1 UNDERLYING SCIENCES *Physics; Chemistry; Biology*			
1.2 UNDERLYING MATHEMATICS *Calculus; Linear Algebra; Differential Equations; Statistics*			
1.3 MECHANICS OF SOLIDS *Force and Moment Equilibrium; Conditions of Geometric Fit; Material Behavior*			
1.4 MECHANICAL BEHAVIOR OF MATERIALS *Elasticity, Fracture, Fatigue, Plasticity, Friction, Wear, Corrosion; Use of Materials in Mechanical Design*			
1.5 SYSTEMS DYNAMICS *Dynamic Modeling and Response; System Functions, Pole-Zeros, and Their Interpretation*			
1.6 DYNAMICS *Kinematics and Dynamics of Bodies in Motion; Behavior of Linearized Models: Natural Modes and Frequency Response, Wave Transmission and Reflection*			
1.7 FLUID MECHANICS *Incompressible Flows; Equations of Fluid Motion*			
1.8 THERMODYNAMICS *1st and 2nd Laws; Pure Substance Models*			
1.9 ENGINEERNIG DESIGN PROCESS *Concept generation; Detail design; Machine elements; Scheduling of Design Activities; Prototype Testing*			
1.10 MANUFACTURNIG *Manufacturing Processes; Systems; Equipment*			

Appendix 3: Frequency/Proficiency/Source Topics and their Descriptions

1) Technical Knowledge
    a. Underlying Sciences: Physics; Chemistry; Biology
    b. Underlying Mathematics: Calculus; Linear Algebra; Differential Equations; Statistics
    c. Mechanics of Solids: Force and Moment Equilibrium; Conditions of Geometric Fit
    d. Mechanical Behavior of Materials: Elasticity; Fracture; Fatigue; Plasticity; Friction; Use of Materials in Mechanical Design
    e. System Dynamics: Dynamic Modeling and Response; System Functions; Kinematics of Bodies in Motion; Frequency Response; Linearized Models
    f. Fluid Mechanics: Incompressible Flows; Equations of Fluid Motion
    g. Thermodynamics: First and Second Laws; Pure Substance Model

h. Heat Transfer: Heat Conduction; Forced and Free Convection; Radiation; Condensation; Boiling; Heat Exchanger Design
i. Engineering Design Process: Concept Generation; Detail Design; Machine Elements; Prototyping
j. Manufacturing: Manufacturing Processes; Systems; Equipment

2) Engineering Skills
   a. Engineering Reasoning: Problem Solving; Problem Identification; Modeling; Quantitative Analysis
   b. Experimentation: Hypothesis Formulation; Experimental Inquiry; Hypothesis Test and Defense
   c. System Thinking: Defining the System and its Interfaces; Interaction in Systems
   d. Idea Development: Setting System Goals and Requirements; Defining Product Function; Modeling of System
   e. Designing: Design Process; Conceptual Design; Trade-off Analysis; Detail Design
   f. Testing: Building a Prototype; Test; Verification and Validation
3) Work Environment
   a. Independent Thinking: Setting Project Goals; Working Independently
   b. Teamwork: Goal Setting; Scheduling
   c. Leadership: Decision Making; Organization and Delegation; Negotiation; Ability to Motivate Others; Risk Management
   d. Communication: Written; Multimedia; Graphical; Oral Presentation; Communication to those Outside the Field
4) Professional Skills and Attributes
   a. Personal Skills: Willingness to Take Risks; Creative Thinking; Time and Resource Management
   b. Professional Attributes: Ethics; Integrity; Continuous Learning
   c. External and Societal Context: Responsibilities of Engineers on Society; Global Perspective
   d. Business Context: Enterprise Strategy; Goals and Planning; Entrepreneurship; Working with Organizations
   e. Market Context: Market Opportunities; Customer Needs; Financial Planning for New Products

Appendix 4: Kristen Wolfe's Occupation List

Engineer
Technical Manager
Consultant
Doctor
Attorney
Professor
Non-Academic Researcher
Member of the Military
Not currently employed outside the home
Other

Appendix 5: Modified Occupation List

(Changes marked with an asterisk*)

Engineer
Manager*
Consultant
Banking/Finance*
Doctor
Attorney
Professor (College or University)*
Currently Out of the Work Force*
Student*
Other

Appendix 6: List of Tasks

Creating or Modifying:
- Designing or conducting performance tests or building testing rigs
- Writing code
- Conducting analyses of the physics of a product
- Reworking a project decision to compensate for a misunderstanding
- Modifying the design of an existing component

Communicating or Interacting
- Reading or sending email
- Responding to requests or questions from others
- Interviewing candidates
- Meeting with one or more members of your project team
- Meeting with other company employees or organization members
- Interacting with customers or users
- Communicating with vendors or suppliers
- Planning or organizing a person's or team's activities

Planning or Designing
- Documenting projects or outcomes
- Mining previous projects or reports for information
- Developing a project strategy or direction
- Creating or modifying a CAD representation
- Planning a code-building cycle
- Working alone to make project decisions
- Evaluating competitors' products

Appendix 7: Final Survey

This section serves to show the order and format in which the questions were asked. The conditional questions for occupation are not shown, but are identical in format to the occupation questions themselves.

The task list is not shown in full in the screenshot of the survey, but a full list is provided in Appendix 6. The same goes for the Frequency of Use, Expected Proficiency, and Source questions; their full list is provided in Appendix 3.

DEPARTMENT OF MECHANICAL ENGINEERING

MITMECHE

Welcome !

Hello and thank you for taking part in this survey examining the careers of the alumni of the Mechanical Engineering Department at MIT. As an MIT alumnus with experience after graduation, you can offer insightful information about the skills and knowledge that you have found most useful (or not useful) in your career. This data will help identify ways in which the undergraduate curriculum could be modified, and will inform current students about possible career paths.

The survey is voluntary. Please be assured that the data will be treated as confidential, and the results of any research or analysis using the data will be presented in a way that individual respondents cannot be identified. If data from this survey are used for academic research, the same rules of confidentiality and reporting apply.

Kelly Wang, Class of 2015, Department of Mechanical Engineering
Professor Warren Seering, Department of Mechanical Engineering

>> Next

What is your current occupation and background?

Please select the option that most closely describes your CURRENT occupation.

Engineer

Manager

Consultant

Banking/Finance

Doctor

Attorney

Professor (College or University)

Currently Out of the Work Force

Student

Other

Please select the option(s) that most closely describes any degree(s) that you have received to date in addition to your BS from our department.

N/A

PhD

Masters Degree in Engineering

Law School

Masters of Engineering Management

Medical School

MBA

Other (please specify)

Please select the option that most closely describes your FIRST occupation after graduating from MIT.

Same as current occupation

Engineer

Manager

Consultant

Out of the Work Force

Student

Other

How many different companies have you been employed at full-time since you received your Bachelor of Science degree from MIT?

How many years have you worked at your CURRENT place of employment?

What do you spend work time on every week?

Which of these things did you spend more than five hours on last week?

Planning or Designing

Documenting projects or outcomes

Planning a code-building cycle

Working alone to make project decisions

Creating or modifying a CAD representation

Mining previous projects or reports for information

Evaluating competitors' products

Developing project strategy or direction

None of the above

How often do you use particular technical knowledge or skills?

Please select the option to describe how often you use the knowledge or skills from each category.

TECHNICAL KNOWLEDGE

	Never	A Few Times a Year	At Least Once a Month	At Least Once a Week	On Most Days	For Almost Everything I Do
Underlying Sciences *Physics; Chemistry; Biology*	○	○	○	○	○	○
Underlying Mathematics *Calculus; Linear Algebra; Differential Equations; Statistics*	○	○	○	○	○	○
Mechanics of Solids *Force and Moment Equilibrium; Conditions of Geometric Fit*	○	○	○	○	○	○
Mechanical Behavior of Materials *Elasticity; Fracture; Fatigue; Plasticity; Friction; Use of Materials in Mechanical Design*	○	○	○	○	○	○
System Dynamics *Dynamic Modeling and Response; System Functions; Kinematics of Bodies in Motion; Frequency Response; Linearized Models*	○	○	○	○	○	○

Where did you gain your knowledge or skills?

Please select the best option to describe <u>where you gained the majority of your understanding</u> in the following categories. If there is more than one source, please rank your primary and secondary sources.

Engineering Reasoning
Problem Solving; Problem Identification; Modeling; Quantitative Analysis

	Undergraduate Program at MIT	Graduate Program	Company-Sponsored Training Program	Work Experience	Elsewhere
Primary	☐	☐	☐	☐	☐
Secondary (if applicable)	☐	☐	☐	☐	☐

Experimentation
Hypothesis Formulation; Experimental Inquiry; Hypothesis Test and Defense

	Undergraduate Program at MIT	Graduate Program	Company-Sponsored Training Program	Work Experience	Elsewhere
Primary	☐	☐	☐	☐	☐
Secondary (if applicable)	☐	☐	☐	☐	☐

System Thinking
Defining the System and Its Interfaces; Interaction in Systems

	Undergraduate Program at MIT	Graduate Program	Company-Sponsored Training Program	Work Experience	Elsewhere
Primary	☐	☐	☐	☐	☐
Secondary (if applicable)	☐	☐	☐	☐	☐

How proficient do you need to be in specific areas?

Please select the best option to describe <u>how proficient you are expected to be</u> in the following categories.

	To essentially have no knowledge of	To have some experience or exposure in	To be able to participate in and contribute to	To be able to understand and explain	To be skilled in the practice and implementation of	To be able to innovate and lead in
Independent Thinking *Setting Project Goals; Working Independently*	○	○	○	○	○	○
Teamwork *Goal Setting; Scheduling*	○	○	○	○	○	○
Leadership *Decision Making; Organization and Delegation; Negotiation; Ability to Motivate Others; Risk Management*	○	○	○	○	○	○
Communication *Written, Multimedia; Graphical; Oral Presentation, Communication to those Outside of the Field*	○	○	○	○	○	○

Summing Up

Thank you very much for taking the time to complete this survey. The past questions have been focused on specific knowledge and skills. We now want to open it up to a broader scope.

What aspects in your MIT experience have been most valuable for you professionally? Please list up to three.

1

2

3

If applicable, how did your college internships influence your career decision?

Faculty from the MIT Schools of Engineering and Management are considering the possibility of offering continuing professional education opportunities for alumni, in formats including online classes, resident short courses, and degree programs. If MIT were to offer courses such as these, what topics would you like to see included? Please list up to five topic areas.

1

2

3

4

5

Would you be willing to take part in future focus groups that might be set up on the results of this study? Please indicate your interest by checking yes and entering an email address where you are best reached. Your contact email will be disconnected from your survey responses.

Appendix 8: Correspondence Emails

First Email Correspondence:

Email Subject: MIT Study on Careers of MechE Alumni

Dear [name],

As the needs of our Mechanical Engineering undergraduates evolve, we are working to see that our program keeps pace. To enable us to improve, we need to understand what knowledge is of value to our alumni and the paths that their careers are taking. We're reaching out to you with the hope that you will be willing to help us gather this information.

Our goal for this project is to learn about the professional activities of our alumni over their various careers in order to discern what they do specifically in their jobs. We intend to use this information to tailor our department's curriculum to reflect the needs of our alumni. Additionally, we want to share this aggregate knowledge about alumni careers with our current mechanical engineering undergraduates with hope that consequently they will be able to make more informed decisions about their own career directions.

You can help us to accomplish this by filling out our career survey.

[unique link]

This is a unique link, given only to you, so please do not share it with others or forward this email to others. This survey should take about 15 minutes to complete, and the information gathered will be very valuable to us.

We sincerely appreciate your willingness to help.

Warren Seering
Weber-Shaughness Professor of Mechanical Engineering

First Reminder Email:

Email Subject: Professional paths of MIT MechE Alumni
Dear [name],

My name is Kelly Wang, and I am a senior at MIT in the Mechanical Engineering Department. As a soon-to-be graduate of the institute, I have become increasingly curious about the various professional paths of our department's alumni, and have therefore decided to focus my thesis on exactly that. I am working with the department in the hopes to gather information on the professional skills of our alumni, looking to determine what they do specifically in their jobs and the knowledge utilized in their careers.

About a week ago, you received an email from Professor Seering with a link for the Mechanical Engineering Alumni Survey. Fifteen minutes of your time with this survey will help tremendously in my efforts to provide the department with a better understanding of the professional lives of their graduates and to collect the data for my thesis.

The questionnaire is available via your personal web link:
[unique link]

Thank you for your help,
Kelly Wang

Second/Final Reminder Email:

Email Subject: Influence the trajectories of future MIT MechE students
Dear [name],

I'm following up Kelly Wang's recent note, hoping that you will find time in the next few days to respond to our Course 2 alumni careers survey. Knowledge of the needs of our graduates is most helpful to us as we consider future program and curricular options.

The information we've received so far is giving us an understanding of the professional lives of our alumni that we have not had before. Your response will enable us to look more carefully into the trajectories of each graduating class so that we can understand your professional needs over time. Your taking 15 minutes (mean 14.96, s.d. 9.94 so far) will be very, very helpful to us in this regard. We will need your response soon so that Kelly can include your data in her thesis.

Thank you for considering our request. Your responding will be important for us and for future graduates of our department. Kelly and I sincerely appreciate your help.

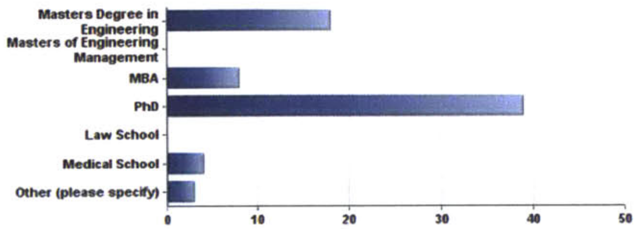
Warren Seering
Weber/Shaughness Professor of Mechanical Engineering

Kelly Wang
Class of 2015 (!)
[unique link]

Appendix 9: Advanced Degree Responses

Prompt: Please select the option that most closely describes the degree program that you are enrolled in.

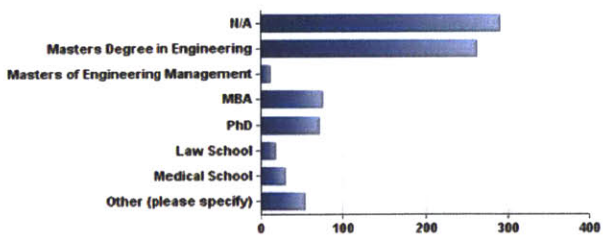
Responses (taken directly from Qualtrics):



#	Answer		Response	%
1	Masters Degree in Engineering		18	25.0%
2	Masters of Engineering Management		0	0.0%
3	MBA		8	11.1%
4	PhD		39	54.2%
5	Law School		0	0.0%
6	Medical School		4	5.6%
7	Other (please specify)		3	4.2%
	Total		72	100.0%

Prompt: Please select the option(s) that most closely describes any degree(s) that you have received to date in addition to your BS from our department.

Responses (taken directly from Qualtrics):



#	Answer		Response	%
1	N/A		291	40.2%
2	Masters Degree in Engineering		263	36.3%
3	Masters of Engineering Management		12	1.7%
4	MBA		76	10.5%
5	PhD		72	9.9%
6	Law School		18	2.5%
7	Medical School		29	4.0%
8	Other (please specify)		54	7.5%

Appendix 10: Old 2-A Requirements

Old 2-A Requirements (for class of 2015 and earlier):
GIRs: Biology, Chemistry, Calculus I & II, Physics I & II, 8 HASS, REST: 18.03 + 2.001, Lab: 2.671
Communications Requirement: 2 CI-H, 2 CI-M: 2.671 + 2.009

Departmental Program
Required Departmental Core Subjects
2.001 Mechanics & Materials I, 12, REST; Physics I, Calc II, *18.03*
2.003J Dynamics & Control I, 12, REST; Physics I, 18.03
2.005 Thermal-Fluids Engineering I, 12, REST; Physics II, Calc II, *18.03*
2.009 The Product Engineering Process, 12, CI-M; 2.001, 2.003J, 2.005; 2.00B or 2.670; senior standing or permission of instructor
2.670 Mechanical Engineering Tools, 3
2.671 Measurement & Instrumentation, 12, LAB, CI-M; 2.001, 2.003, Physics II
18.03 Differential Equations, 12, REST; *18.02*

Two Additional Mechanical Engineering Subjects
2.002 Mechanics & Materials II, 12; 2.001, Chemistry
2.004 Dynamics & Control II, 12; 2.003J, Physics II
2.006 Thermal-Fluids Engineering II, 12; 2.005, 18.03
2.007 Design & Manufacturing I, 12; 2.001
2.008 Design & Manufacturing II, 12, 1/2 LAB; 2.001; *2.005*; 2.007 or *2.017J*
2.086 Numerical Computation for Mechanical Engineers, 12; Physics I, Calc II, 18.03
2.ThU Undergraduate Thesis, 12

Elective Subjects with Engineering Content: 72 units (your 2-A concentration)
Unrestricted Electives: 48 units
Total Units Beyond the GIRs Required for SB Degree: 183

References

1) Wolfe, K., 2004, "Understanding the Careers of the Alumni of the MIT Mechanical Engineering Department," Undergraduate Thesis, Massachusetts Institute of Technology, Cambridge, MA.
2) Kelly, C., 2003, "Some Trends in the Career Paths Followed by Alumni of the MIT Mechanical Engineering Department," Undergraduate Thesis, Massachusetts Institute of Technology, Cambridge, MA.
3) Batra, N., 2010, ""A Look to the Future: MIT Alumni and their Course 2 and 2-A Educational Experience," Undergraduate Thesis, Massachusetts Institute of Technology, Cambridge, MA.