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Understanding the Careers of the Alumni of the MIT Mechanical Engineering Department

by

Kristen E. Wolfe

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 2004

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ABSTRACT

This research seeks to understand the careers of MIT mechanical engineering alumni. Data was collected to determine the knowledge and skills that graduates from the classes of 1992 through 1996 make use of in their professions. Data was collected on many topics in four areas: technical knowledge and reasoning, personal and professional skills and attributes, interpersonal skills, and engineering skills. The topics were ranked in terms of expected proficiency, frequency of use, and source of knowledge. The data is presented and implications for improving the mechanical engineering curriculum are discussed.

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

This thesis is dedicated to my parents, Karen and Chuck Wolfe. Their love and support over the past 22 years of my life has made it possible for me to achieve all that I have accomplished.

Mom, you have given so much of your time and energy to me. This thesis is as much your work as mine. I love you.

Special Thanks to...

Barbara Masi, William Lucas, Dan Frey, Steven Dubowsky, Ela Ben-Ur, Arlene Spezzaferro, Frank DeSimone, the MIT Mechanical Engineering Council, and the Engineering Committee on Undergraduate Education for their feedback and discussion with me over the last year, enabling me to think more deeply about my research.

Professor Seering who made this research possible and supported my efforts along the way. Also for being a trusted mentor as I pursue my career as an educator.

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Chapter 1: Introduction and Literature Review

The purpose of this research is to understand more clearly what knowledge and skills graduates of the MIT Mechanical Engineering Department make use of in their professions. The vision and mission of this research are as follows:

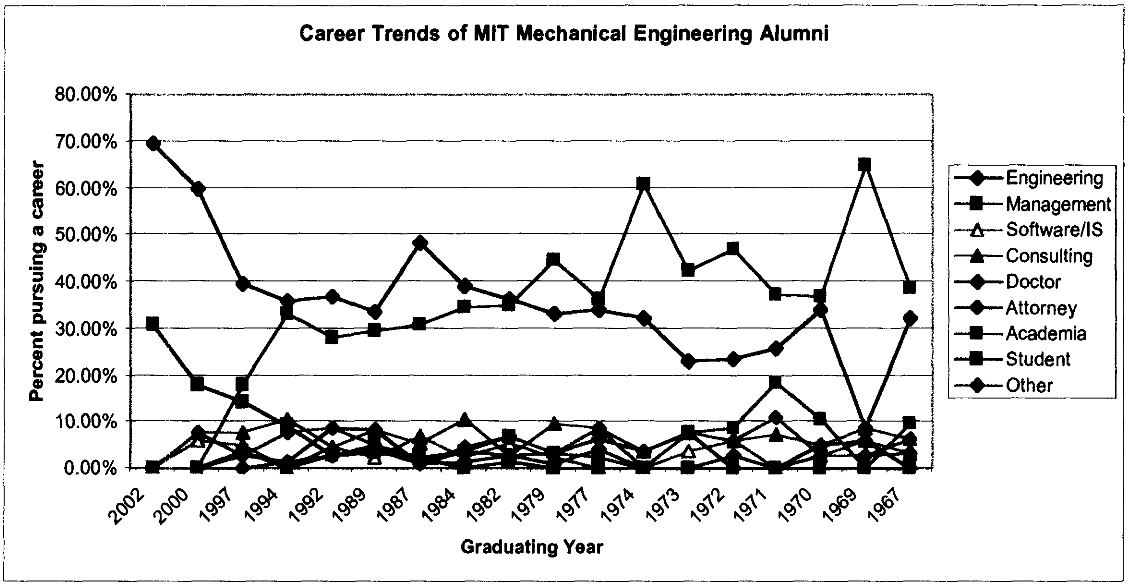
VISION: The mechanical engineering curriculum will prepare our graduates to be leaders in their chosen professions. By leaders we mean the people in a given profession who are highly regarded by their peers and other professional colleagues.

MISSION: We will learn about the professional activities of our graduates in order to discern what specifically they do in their jobs, and then use that to tailor our curriculum to reflect the needs of our alumni.

The hope is that by better understanding what MIT mechanical engineering graduates need and use in their professions, the department can then know how to better prepare the undergraduate students for their futures.

Background:

My work follows on the research of Catherine Kelly in her undergraduate thesis entitled Some Trends in the Career Paths Followed by Alumni of the MIT Mechanical Engineering Department [1]. Her research focused on determining what careers graduates chose after leaving MIT. She obtained data on the current occupations of the graduating classes of 1967 through 2002. Her results can be seen on the graph below:



As can be seen above, Catherine Kelly found that approximately 70% of MIT mechanical engineering graduates enter into technical fields while the others pursue a wide variety of career paths. Within the technical career paths, the graduates diverge over time into focusing on either the management or the engineering realm. For more detail about Kelly's thesis, see Appendix 1.

To understand better the results that Catherine Kelly obtained, I replicated one year of her data following the procedure she used, as described in her thesis. I obtained the same results she did. I then analyzed two additional years that she had not done. My results fit neatly into Kelly's results confirming that the trends she found are constant over time with only some nominal fluctuations.

Catherine Kelly's results and her finding that the majority of mechanical engineering graduates do not remain in engineering formed the basis for my research. I wanted to take her research a step further: to know not only what variety of careers graduates have, but also what knowledge and skills they need and use in those careers.

Literature Review:

To obtain a broader background on the education and careers of engineers, I spent a month solely on library research. My goal was to determine what research had been done in regards to the careers and education of engineers. I hoped to find information that would confirm and supplement the work that Catherine Kelly did in her thesis.

I started by looking for research done within MIT. Professor Lotte Bailyn in the Sloan School of Management has done some research with alumni careers. I read a paper she wrote, "A Taxonomy of Technically Based Careers" [2] and a book she published, "Living with Technology: Issues at Mid-Career"[3]. Her research was similar in nature to Catherine Kelly's in determining the career trends of MIT alumni. Prof. Bailyn took a broader approach, looking at alumni of the Institute rather than just a department, but found a similar trend in graduates entering into management fields as time progressed. Prof. Bailyn also looked at how various factors influence career choices, such as gender and family.

Prof. Bailyn's work led me to discover another paper written at MIT on a similar topic. D. Kolb and M. Goldman wrote a paper entitled "Toward a Typology of Learning Styles and Learning Environments: An investigation of the Impact of Learning Styles and Discipline Demands on the Academic Performance, Social Adaptation and Career Choices of MIT Seniors" [4]. The title accurately summarizes the content of the paper. One particularly relevant aspect of this paper was its discussion of discipline demands. They posed the question of whether people with certain learning styles succeed more readily in certain majors. They found it to be the case that those students whose learning styles were more in sync with the discipline demands succeeded more readily and tended to pursue careers associated with their major. This is interesting to consider given Kelly's research showing that mechanical engineering graduates go on to pursue a wide variety of professions.

Also within the MIT community, I spoke with Barbara Masi who conducts research in the School of Engineering and William A. Lucas who is the Associate Director of CMI and conducts research on academic programs. Both were able to direct me to further sources for my research and give me ideas from their own research in similar areas. Barbara Masi was currently involved in a project where she was interviewing MIT alumni about their undergraduate experience at MIT and provided helpful advice on working with alumni. William A. Lucas had previously conducted some research on the topic of how engineers communicate. He provided me with excerpts from his research notes on that topic. The main idea I gathered from his notes was that engineers have trouble communicating with those outside their field.

I then expanded my library research to things done outside of MIT about what engineers should know or need to know in their jobs. I came across two journal articles. "The Graduate" [5] discussed the need for engineers to graduate from college with better business and communication skills. Another article, "An Analysis of Professional Skills in Design: Implication for Education and Research" [6], made a similar point that interpersonal and management skills are necessary for engineers in addition to design competence.

Prof. Seering was familiar with a body of research that Crispin Hales conducted for his PhD at the University of Cambridge entitled, *Analysis of the Engineering Design Process in an Industrial Context* [7]. I wrote to Dr. Hales and he graciously sent me a copy of his dissertation. He was concerned with finding out what actually happened in the engineering design process. He spent many months taking detailed observations of engineers involved in designing a product. He then classified various phases of the design process.

I was also recommended a very newly published book, *Human Behavior in Design* [8]. The book contains a collection of research by various people that was discussed at "Bild und Begriff" workshops. "Bild und Begriff" is German for images and concepts/words. These workshops sought to answer questions pertaining to the connection between images and concepts in engineering design. They examined this connection in the context of humans in design, each person having their own preferences and perceptions. The research is broken down into three topics: individual thinking and acting, interaction between individuals, and methods, tools, and prerequisites.

Although Dr. Hales' work and the work from the Bild und Begriff workshops are quite interesting and well worth reading, they are not directly applicable to this research as I am considering all those who study engineering, not just those who continue in engineering design. Knowing that MIT mechanical engineering graduate pursue such a variety of career paths, the department's curriculum should perhaps incorporate not only the knowledge and skills needed in engineering design, but a broader range of knowledge and skills. My research is concerned with determining the important knowledge and skills that all graduates need.

The general ideas I came away with from my background research that are directly applicable to this thesis are: 1) MIT graduates pursue a wide variety of careers for various reasons, 2) Engineers need to learn more than just knowledge about the physical world, and 3) Engineers need to have business skills such as communication. This provides the foundation for my research into what specific knowledge and skills MIT mechanical engineering graduates use in their professions.

Chapter 2: Creating the Research Method

The idea for this research was to have a better understanding of the knowledge and skills that mechanical engineering graduates make use of in their careers. The graduates selected to be studied are from the classes of 1992 through 1996. These graduates were chosen because this research seeks to determine how best to prepare students to become leaders in their chosen fields. As Prof. Seering explains, "By the age of 30, our alumni will have achieved a level of professional accomplishment sufficient to enable them to begin to accept significant leadership responsibility" [9].

Much brainstorming was done in order to determine the best method for gathering this information from the alumni.

The thought at first was that the best way to understand what mechanical engineering graduates do would be to shadow them. I would spend a day with a graduate and record everything they did. This would allow me to get an intimate view of the careers of selected graduates. However, there were some drawbacks to this method. I would only be able to shadow a limited number of graduates and they would all be in the Boston area. The question also came up about how I would analyze such data. While a collection of case studies would be valuable, it would not give a sense of the graduates as a whole.

The next method considered was interviewing graduates in person or over the telephone. In the interview I would ask the graduate to pull out their calendar and we would discuss what they did in each time slot. I would also ask about various things that were taught at MIT and how important they were now to the graduate. This would be less time consuming than shadowing a graduate for a day and yet give similar results. However, it was still limited in the number of graduates I could speak to.

To expand the number of people I could get information from, the idea developed to use a survey, either alone or in conjunction with an interview. This would allow for many more people to be contacted. Also, a survey opens up a wide variety of possibilities for the data to be gathered. While considering what might be asked in a survey, Prof. Seering came across some research conducted previously by Prof. Edward Crawley in the Department of Aeronautics and Astronautics. This research, done in 2001, was "The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education" [10]. This report and the survey Prof. Crawley designed formed the basis for the survey I would use for my research.

The objective of Prof. Crawley's research was "to create a rational, complete, universal, and generalizable set of goals for undergraduate engineering education". He created the CDIO Syllabus. The name, CDIO, comes from the idea that "graduating engineers should be able to **C**onceive-**D**esign-**I**mplement-

Operate complex value-added engineering systems in a modern team-based environment". The syllabus was designed to cover the areas of knowledge and skills that all engineers should know upon graduation. The Department of Aeronautics and Astronautics has now implemented the CDIO Syllabus in their curriculum. (For further information about their implementation see http://web.mit.edu/aeroastro/www/ or http://www.cdio.org/)

The syllabus created by Prof. Crawley has many levels of detail. Below is the first and second level organization of the CDIO Syllabus:

1 Technical Knowledge and Reasoning
  - 1.1 Knowledge of Underlying Sciences
  - 1.2 Core Engineering Fundamental Knowledge
  - 1.3 Advanced Engineering Fundamental Knowledge

2 Personal and Professional Skills and Attributes
  - 2.1 Engineering Reasoning and Problem Solving
  - 2.2 Experimentation and Knowledge Discovery
  - 2.3 System Thinking
  - 2.4 Personal Skills and Attributes
  - 2.5 Professional Skills and Attitudes

3 Interpersonal Skills: Teamwork and Communication
  - 3.1 Teamwork
  - 3.2 Communications

4 Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context
  - 4.1 External and Societal Context
  - 4.2 Enterprise and Business Context
  - 4.3 Conceiving and Engineering Systems
  - 4.4 Designing
  - 4.5 Implementing
  - 4.6 Operating

For the syllabus with all levels of the detail, see Appendix 2.

Prof. Crawley also wanted to determine how proficient engineering graduates should be in each of the areas on the syllabus. To do this, he surveyed people in industry, academia and alumni. The proficiency levels were measured on the following scale:

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

For the complete survey Prof. Crawley used, see Appendix 3.

One of the claims Prof. Crawley made in his report is that the CDIO Syllabus is generalizable to all engineering disciplines. Working from this assumption, I created the survey to be used in my research.

The first step was to modify the syllabus and survey to reflect the curriculum of the mechanical engineering department. I worked at the third level of organization for the syllabus. The majority of the topics remain unchanged. The biggest difference between my syllabus and the CDIO syllabus is the lack of the terms: conceive, design, implement and operate. Although I kept these general ideas, I changed the 4th section to: Engineering Skills and changed the groupings conceive, design, implement and operate to developing an idea, designing, and testing. Prof. Seering and I believed these terms more accurately captured the engineering process in mechanical engineering.

To fill in the Technical Knowledge and Reasoning Section, I used the MIT Course Catalogues from 1988 to 1996 [11]. Since the survey would be sent to the graduating classes of 1992-1996, I wanted to be certain that the classes they took were accurately depicted in the survey. I included the required courses for a degree in mechanical engineering.

The syllabus in its modified form for mechanical engineering can be seen below: This is the first and second level of organization. The third level was also included in the survey, which will be discussed more later.

* Indicates a modification from the CDIO Syllabus

1 Technical Knowledge and Reasoning
- 1.1 Underlying Sciences*
- 1.2 Underlying Mathematics*
- 1.3 Mechanics of Solids*
- 1.4 Mechanical Behavior of Materials*
- 1.5 System Dynamics and Control*
- 1.6 Dynamics*
- 1.7 Fluid Mechanics*
- 1.8 Thermodynamics*
- 1.9 Heat Transfer*
- 1.10 Engineering Design Process*
- 1.11 Manufacturing*

2 Personal and Professional Skills and Attributes
- 2.1 Engineering Reasoning and Problem Solving
- 2.2 Experimentation and Knowledge Discovery
- 2.3 System Thinking

2.4 Personal Skills and Attributes
2.5 Professional Skills and Attitudes
2.6 Independent Thinking*

3 Interpersonal Skills: Teamwork and Communication
3.1 Teamwork
3.2 Communications

4 Engineering Skills*
4.1 External and Societal Context
4.2 Enterprise and Business Context
4.3 Market Context*
4.4 Developing an Idea*
4.5 Designing*
4.6 Testing*

Prof. Crawley used his survey to determine the expected proficiency level needed in each area of the syllabus. I wanted to know that along with the frequency of use and the source of the knowledge and skills. In addition to the proficiency scale mentioned before I added the following scales:

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 of Knowledge:

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

The combination of proficiency and frequency for each topic allowed for a more comprehensive idea of the value of each topic. The reasoning was that although a graduate may be expected to be highly proficient in a certain area, they might rarely use it, or vice versa. This data can be used to determine which areas need more focus in the mechanical engineering undergraduate program.

The source scale was included to determine how much of the knowledge and skills graduates use they learned at MIT. This data can be used to determine which areas the mechanical engineering undergraduate program is strong in and which areas might need to be added or enhanced.

The survey I created underwent various revisions before it was finalized. Prof. Seering and I spent considerable time discussing each of the areas. Barbara Masi and William A. Lucas were also asked for their feedback about the survey.

To check that the survey adequately covered all areas of knowledge and skills, I compared it with SARTOR (Standards and Routes To Registration), a document published by the Engineering Council in England [12,13]. It discusses the areas in which engineers are required to be competent. The comparison confirmed that my modification of the CDIO syllabus did contain sufficient breadth and depth. See Appendix 4 for more detail.

I wanted to conduct a trial of the survey to see the kinds of responses that I would get from alumni. I contacted three alumni in the Boston area, Ela Ben-Ur, Arlene Spezzaferro, and Frank DeSimone, and asked them to take the survey and give some feedback. From their surveys I was able to get a feel for the type of data to expect and also some helpful suggestions.

The MIT Mechanical Engineering Council also reviewed the survey and provided feedback. The comments and questions from all of these people helped to mold the survey into its final form.

Chapter 3: The Process

From many of the suggestions received, a decision was made to put the survey online for ease of completion and to increase the response rate. The MIT Survey Service was hired to make this possible. I met with Jag Patel to discuss the specifics and we worked together to finalize the online version.

The survey was sent to all MIT Mechanical Engineering graduates from the classes of 1992 through 1996. On March 29, 2004, these 676 graduates were contacted by email, told the vision and mission of the research and asked for their participation. In the email they were provided with a link to the online survey.

Below is a screen shot of a section of the online survey showing the presentation of the directions, which were shown at the top of every page:

MIT Mechanical Engineering Alumni Survey

Page 2 of 5

1 2 3 4 5

This survey enumerates various types of knowledge and sets of skills associated with engineering. Please rank each topic according to the three criteria given below. To help us with data reduction it is important that your responses be based on the 'anchoring descriptions' associated with the numbers 0 through 5. Please refer to these descriptions as you answer the questions. Thanks for your attention to this experimental issue.

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

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

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

Below is a screen shot of a section of the online survey showing the presentation of the knowledge and skills as they were asked to the respondents:

TECHNICAL KNOWLEDGE AND REASONING	**Expected Proficiency** 0=no knowledge of 1=been exposed to 2=participate in 3=understand and explain 4=skilled in the practice 5=able to lead or innovate	**Frequency of Use** 0=never 1=a few times a year 2=at least once a month 3=at least weekly 4=on most days 5=for most everything I do	**Source of Your Knowledge** U=Undergrad G=Grad J=Job E=Elsewhere, N=Didn't Learn
	0 1 2 3 4 5	**0 1 2 3 4 5**	**U G J E N**
1. UNDERLYING SCIENCES *Physics; Chemistry; Biology*	O O O O O O	O O O O O O	O O O O O
2. UNDERLYING MATHEMATICS *Calculus; Linear Algebra; Differential Equations; Statistics*	O O O O O O	O O O O O O	O O O O O
3. MECHANICS OF SOLIDS *Force and Moment Equilibrium; Conditions of Geometric Fit; Material Behavior*	O O O O O O	O O O O O O	O O O O O
4. MECHANICAL BEHAVIOR OF MATERIALS *Elasticity, Fracture, Fatigue, Plasticity, Friction, Wear, Corrosion; Use of Materials in Mechanical Design*	O O O O O O	O O O O O O	O O O O O

The survey consisted of four pages laid out in the format shown above.

The fifth and final page asked the respondents to indicate their current profession. It also included the question: "So far we have been asking about specific knowledge and skills. We now want to open up to a broader scope. What were the most meaningful aspects of your MIT experience for you? (List up to 3)." Although this question does not directly pertain to my research, a discussion of the responses can be found in Appendix 6.

People who did not respond to the survey within a week were sent a follow-up email reminder. Prof. Seering sent a final follow-up email two weeks later. The survey closed May 1, 2004. 308 graduates responded, a 46% response rate.

See Appendix 5 for copies of all correspondence sent to alumni including the complete survey.

I received the data from the MIT Survey Service as comma-separated variables for analysis. The data was in five separate files corresponding to the five pages of the survey. Each file was laid out as shown below, with many more rows for respondents and many more columns for the other knowledge and skill areas.

id	timestamp	Q1PROF.01	Q1FREQ.01	Q1SOUR.01	Q1PROF.02
43003	3/29/04 14:09	2	2	1	3
43007	4/7/04 17:08	1	1	1	1
43011	4/8/04 15:15	4	4	1	5
43016	4/7/04 22:36	4	2	1	3

The ID number is a random number that was assigned to each person who received the survey. I used ID numbers instead of names to protect the anonymity of the respondents. The timestamp indicates the time at which each respondent took the survey. Q1PROF.01 refers to the topic: the Q1 indicates that this is in the first section, technical knowledge and reasoning; PROF refers to which scale is being used (proficiency, frequency or source); .01 indicates that this is the first question in the section, in this case, underlying sciences.

Before I could begin to analyze the data, I had to manipulate it into a usable form. First I wanted to combine the five files for each page of the survey into one larger file. I used the copy and paste functions in Excel to do this. One problem arose from this, not all respondents completed all pages of the survey. If a respondent completed pages 1 through 3 and then stopped, they would have a row on pages 1, 2, and 3, but not on pages 4 and 5. Because of this, I had to go through each line of the data and match up ID numbers. On the later pages, this meant adding cells for those people who had only completed some of the survey and then stopped. I then also went through the data and deleted anyone who did not answer any of the questions.

The next step in manipulating the data was to sort it into three separate files, one for proficiency, one for frequency and one for source. I again did this by using the cut and paste functions in Excel. A sample of the data file for proficiency is shown below.

ID#	UNDERLYING SCIENCES	UNDERLYING MATHEMATICS	MECHANICS OF SOLIDS
43199	4	4	4
43122	5	6	6
43367	4	4	2
43623	4	4	3
43645	5	5	6

There was one more step in the manipulation before the data was ready to be analyzed. Notice in the file above that there are some 6's as responses. The scales used in the survey ranked proficiency and frequency from 0-5, but the data was coded using numbers 1-6. To make the data match the scale, I had to subtract 1 from every value in the table. This was done after making the switch from Excel to SPSS (Statistical Package for the Social Sciences). I used the "recode variables" function to map 6→5, 5→4, etc.

After these steps of data manipulation, the data was ready to be analyzed. For the analysis, I found it easiest to run the numbers in SPSS and then transfer back to Excel to plot my results.

Chapter 4: Analysis of Data

Proficiency:

For each knowledge and skill area the graduates were asked to rate expected proficiency. The question was phrased as such:

> 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?
>
> 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

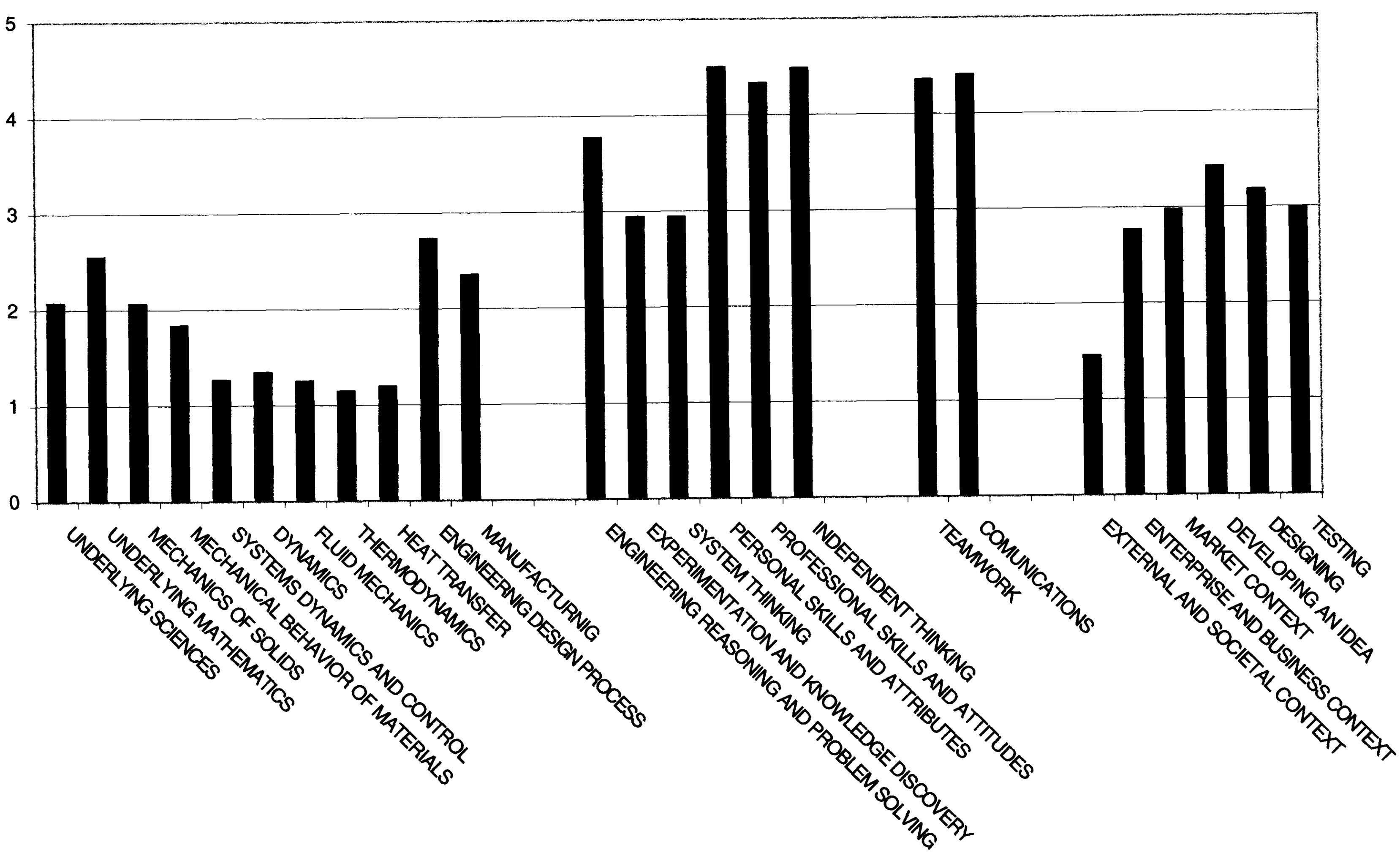
The first way I looked at the data was in terms of the mean expected proficiency. I used the "descriptives" function to find this. The output from SPSS is shown on the next page.

Descriptive Statistics
Expected Proficiency

	N	Minimum	Maximum	Mean	Std. Deviation
Underlying Science	305	0	5	2.07	1.438
Underlying Mathematics	305	0	5	2.55	1.357
Mechanics of Solids	304	0	5	2.06	1.460
Mechanical Behavior of Materials	305	0	5	1.83	1.748
Systems Dynamics and Control	302	0	5	1.26	1.394
Dynamics	303	0	5	1.34	1.423
Fluid Mechanics	302	0	5	1.25	1.366
Thermodynamics	302	0	5	1.14	1.256
Heat Transfer	301	0	5	1.19	1.312
Engineering Design	302	0	5	2.73	1.999
Manufacturing	301	0	5	2.35	1.875
Engineering Reasoning and Problem Solving	297	0	5	3.77	1.527
Experimentation and Knowledge Discovery	297	0	5	2.94	1.668
System Thinking	296	0	5	2.94	1.852
Personal Skills and Attributes	297	1	5	4.49	.736
Professional Skills and Attitudes	297	1	5	4.33	.783
Independent Thinking	297	1	5	4.48	.740
Teamwork	291	0	5	4.35	.856
Communication	292	0	5	4.40	.709
External and Societal Context	290	0	5	1.45	1.414
Enterprise and Business Context	291	0	5	2.76	1.642
Market Context	291	0	5	2.97	1.683
Developing an Idea	291	0	5	3.42	1.649
Designing	290	0	5	3.18	1.744
Testing	289	0	5	2.99	1.793
Valid N (listwise)	268				

I transferred the mean values to Excel and plotted, as seen on the next page.

Mean Expected Proficiency



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.

The chart shows that the areas with the largest proficiencies are personal skills, professional skills, independent thinking, teamwork and communication. Engineering reasoning and problem solving is close behind. The areas with the lowest proficiency fall in the technical knowledge and reasoning categories.

To understand better the meaning of these averages, I looked at the numbers that people reported for each area. I used the "frequencies" function to do this. A sample of the output from SPSS is shown below.

Underlying Science

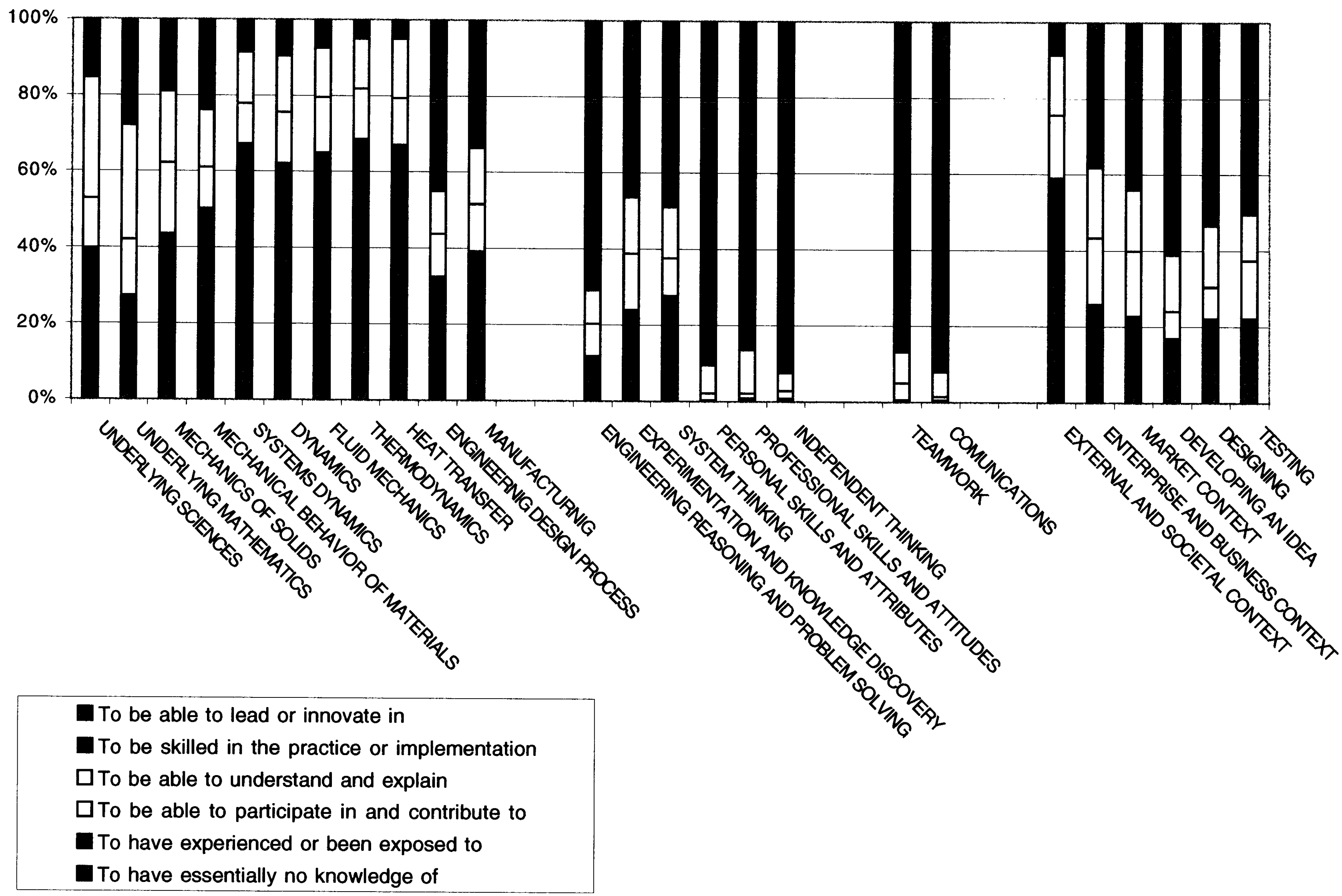
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	58	18.8	19.0	19.0
	1	63	20.5	20.7	39.7
	2	40	13.0	13.1	52.8
	3	97	31.5	31.8	84.6
	4	37	12.0	12.1	96.7
	5	10	3.2	3.3	100.0
	Total	305	99.0	100.0	
Missing	System	3	1.0		
Total		308	100.0		

Underlying Mathematics

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	24	7.8	7.9	7.9
	1	59	19.2	19.3	27.2
	2	45	14.6	14.8	42.0
	3	92	29.9	30.2	72.1
	4	72	23.4	23.6	95.7
	5	13	4.2	4.3	100.0
	Total	305	99.0	100.0	
Missing	System	3	1.0		
Total		308	100.0		

SPSS gave similar tables for each of the knowledge and skill areas. I transferred the numbers in the frequency column to Excel and plotted, as seen on the next page.

Expected Proficiency



At first look, it appears from the data that hardly anyone has a need to be highly proficient in the core mechanical engineering material. The question can then be posed, are the same people giving 5's across the board, or are different people giving 5's to different topics. Using the "select cases" function in SPSS, I was able to address this question. I selected those cases in which the respondent ranked at least one area as a 5. This was 17%. I then selected those cases in which the respondents ranked at least one area as a 4 or 5. This was 43%. These numbers seem to indicate that the graduates have become specialized in their fields and each of the technical knowledge areas has great value to a different section of people.

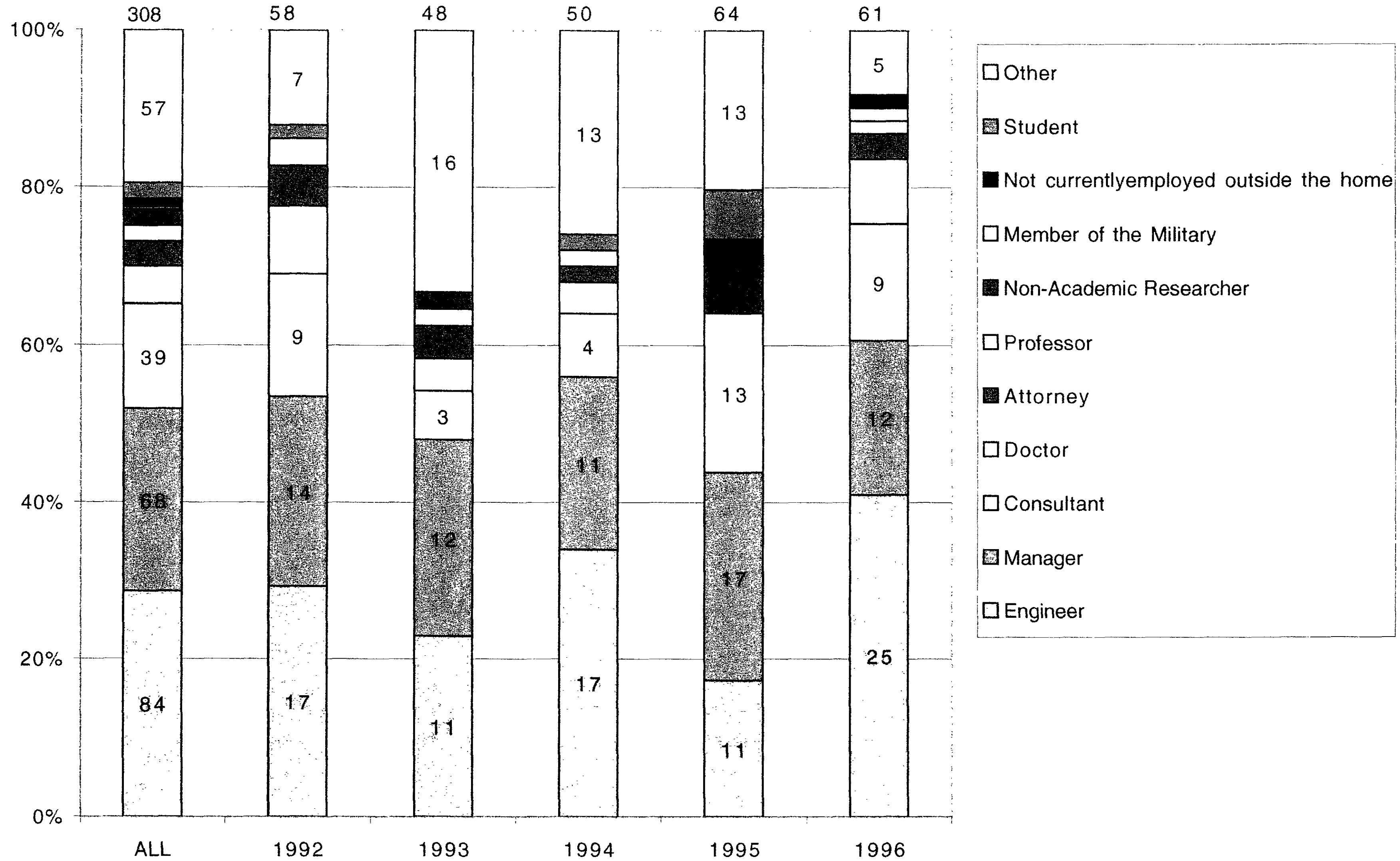
Another important consideration when looking at this data is what profession the respondents are in. As Catherine Kelly found in her thesis, MIT mechanical engineering graduates go on to a wide variety of careers. The survey asked the graduates to indicate their current profession. The choices were: engineer, technical manager, consultant, doctor, attorney, professor, non-academic researcher, member of the military, not employed outside the home, student, and other. In the case of "other" I went through individually and looked at the job description. In some cases, I recoded the job to a different category. This was done to remain consistent with Catherine Kelly's classifications. I used the "frequencies" function again to determine the number in each profession. The output from SPSS can be seen in the chart below.

Job

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Engineer	84	27.3	28.7	28.7
	Manager	68	22.1	23.2	51.9
	Consultant	39	12.7	13.3	65.2
	Doctor	14	4.5	4.8	70.0
	Attorney	9	2.9	3.1	73.0
	Professor	6	1.9	2.0	75.1
	Non-Academic Researcher	6	1.9	2.0	77.1
	Member of the Military	1	.3	.3	77.5
	Not employed outside the home	3	1.0	1.0	78.5
	Other	57	18.5	19.5	98.0
	Student	6	1.9	2.0	100.0
	Total	293	95.1	100.0	
Missing	System	15	4.9		
Total		308	100.0		

I also used SPSS to distribute the people by graduating class in addition to profession. The distributions can be seen in the chart on the next page. The distribution of survey respondents fits well with what was expected given Catherine Kelly's results.

Survey Respondents

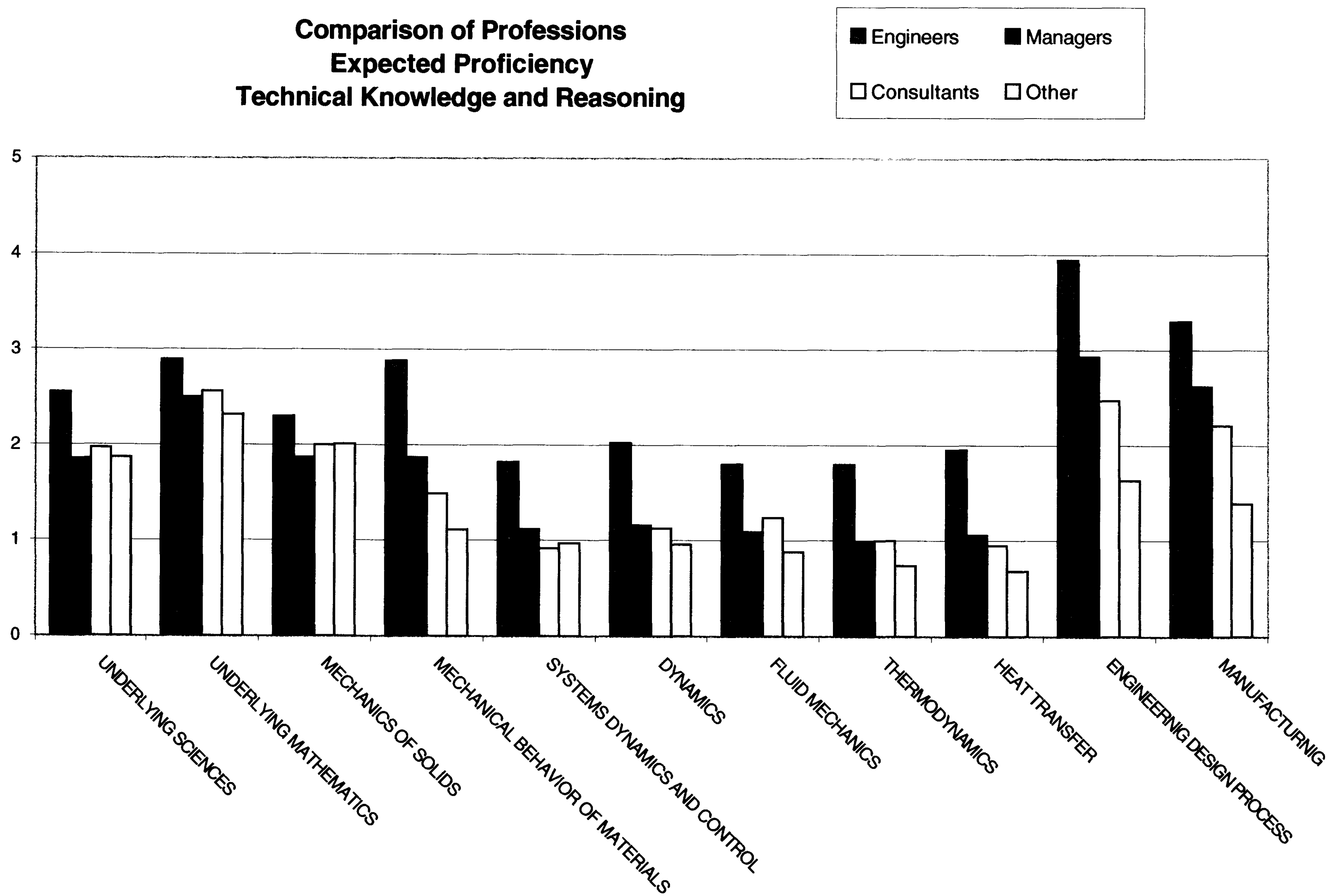


Note the large number of people who self-reported as 'other'. Some of the things they listed are: high school teacher, software engineer, marketing/sales, banker, actuary, Wall Street stock analyst, orthodontist, and affordable housing developer. For the complete list of 'other' professions, see Appendix 7.

Since the respondents' professions were known, I was able to run my analysis of average proficiency again using only selected groups of people. I again used the "select cases" function, this time to select the engineers. I then ran the "descriptives" function to obtain the mean expected proficiency for each area. I repeated this for the managers, consultants, and others (where 'others' now refers not only to those who reported other, but to all those who do not fit into the categories of engineer, manager or consultant). Using Excel, I plotted the mean expected proficiency for each of these groups. In most cases the variance is small, but it is worth noting.

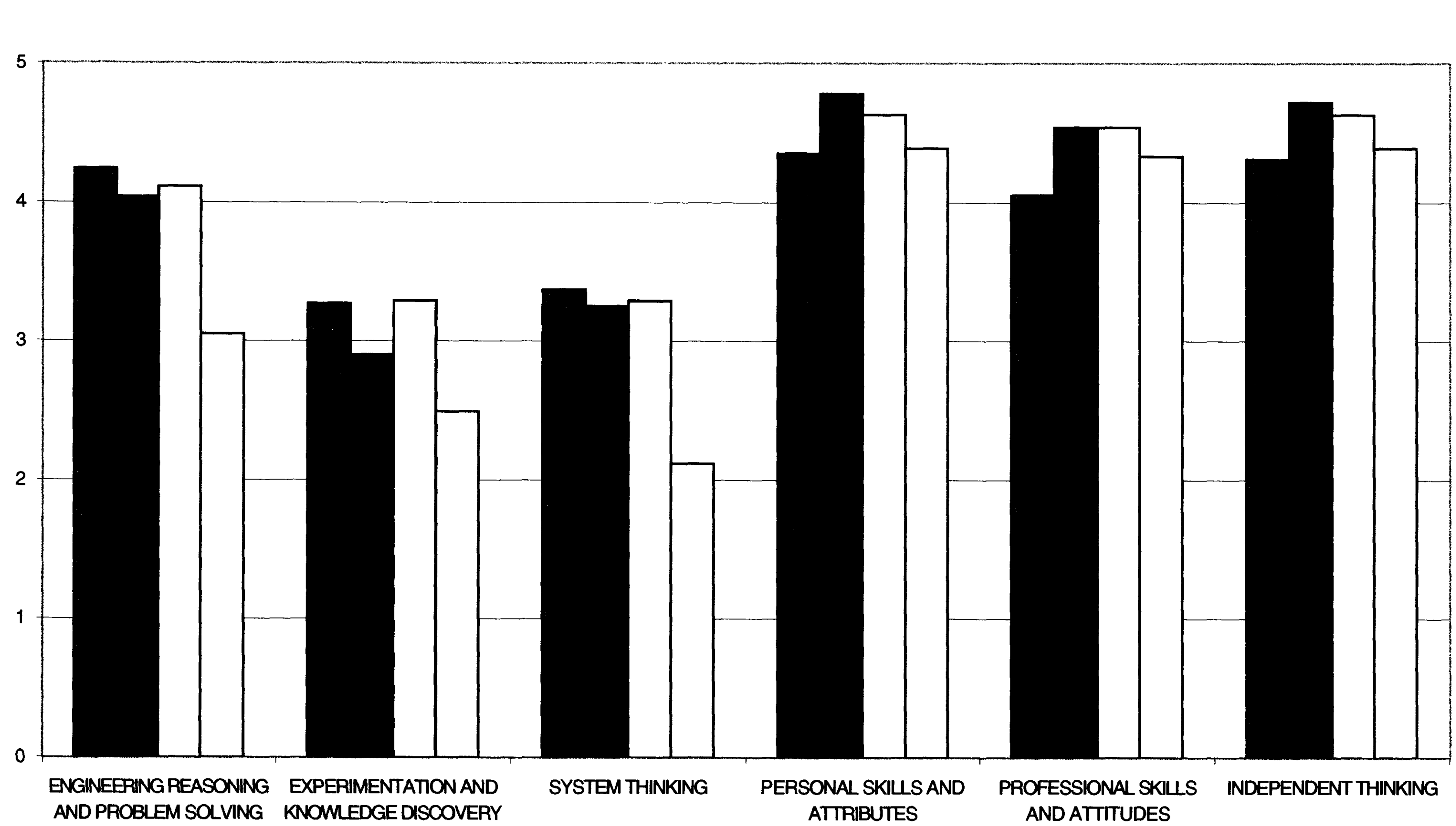
Within the grouping of "other" there are a few interesting variances worth mentioning. Doctors and researchers report the highest expected proficiency in the underlying sciences. Researchers and professors report the highest expected proficiency in underlying mathematics and experimentation and knowledge discovery. Students, on the other hand, report lower than average expected proficiency across the board.

Another correlation was considered: graduating year. I ran the same analysis described above for graduating year. However, the differences were negligible.



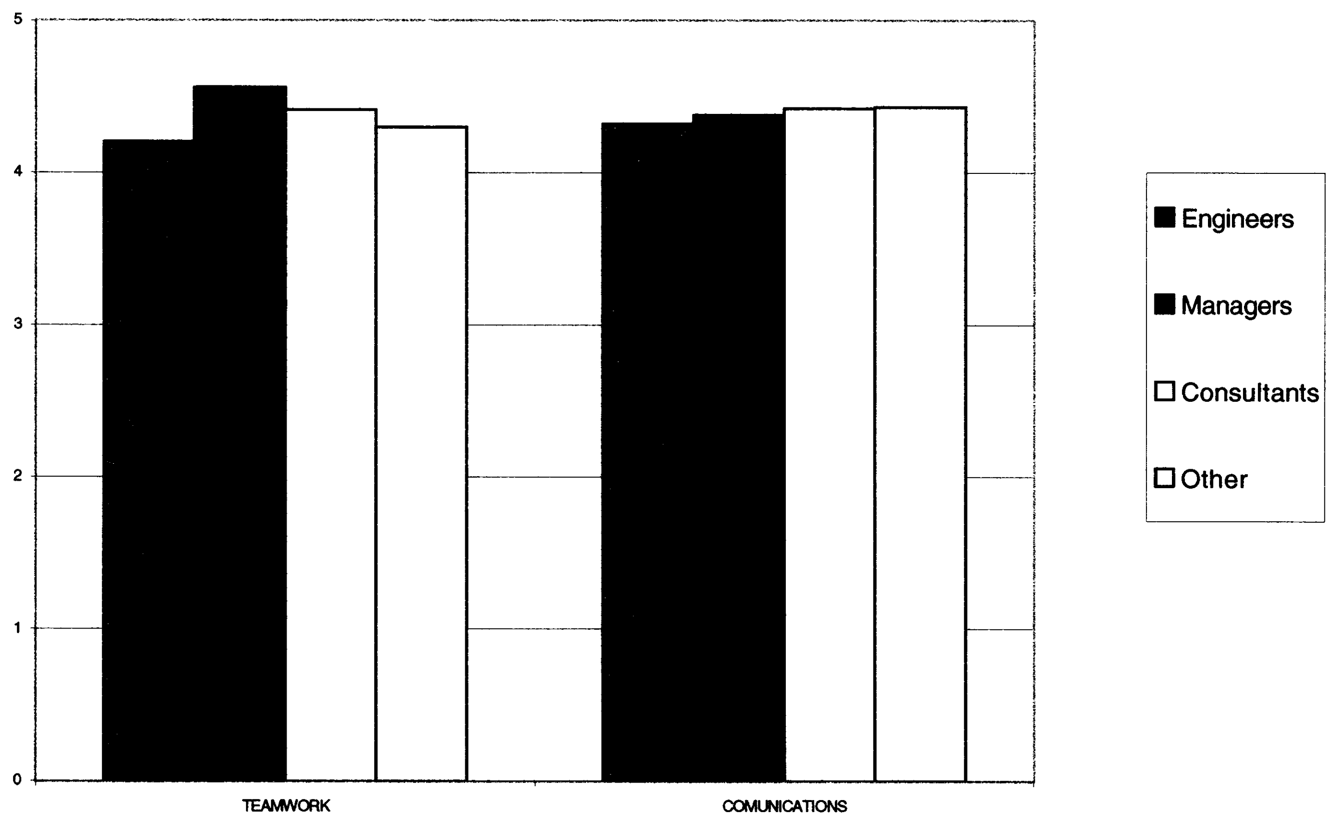
0 No knowledge of, 1 been exposed to, 2 participate in, 3 understand and explain, 4 skilled in the practice, 5 lead or innovate in

Comparison of Professions
Expected Proficiency
Personal and Professional Skills and Attributes

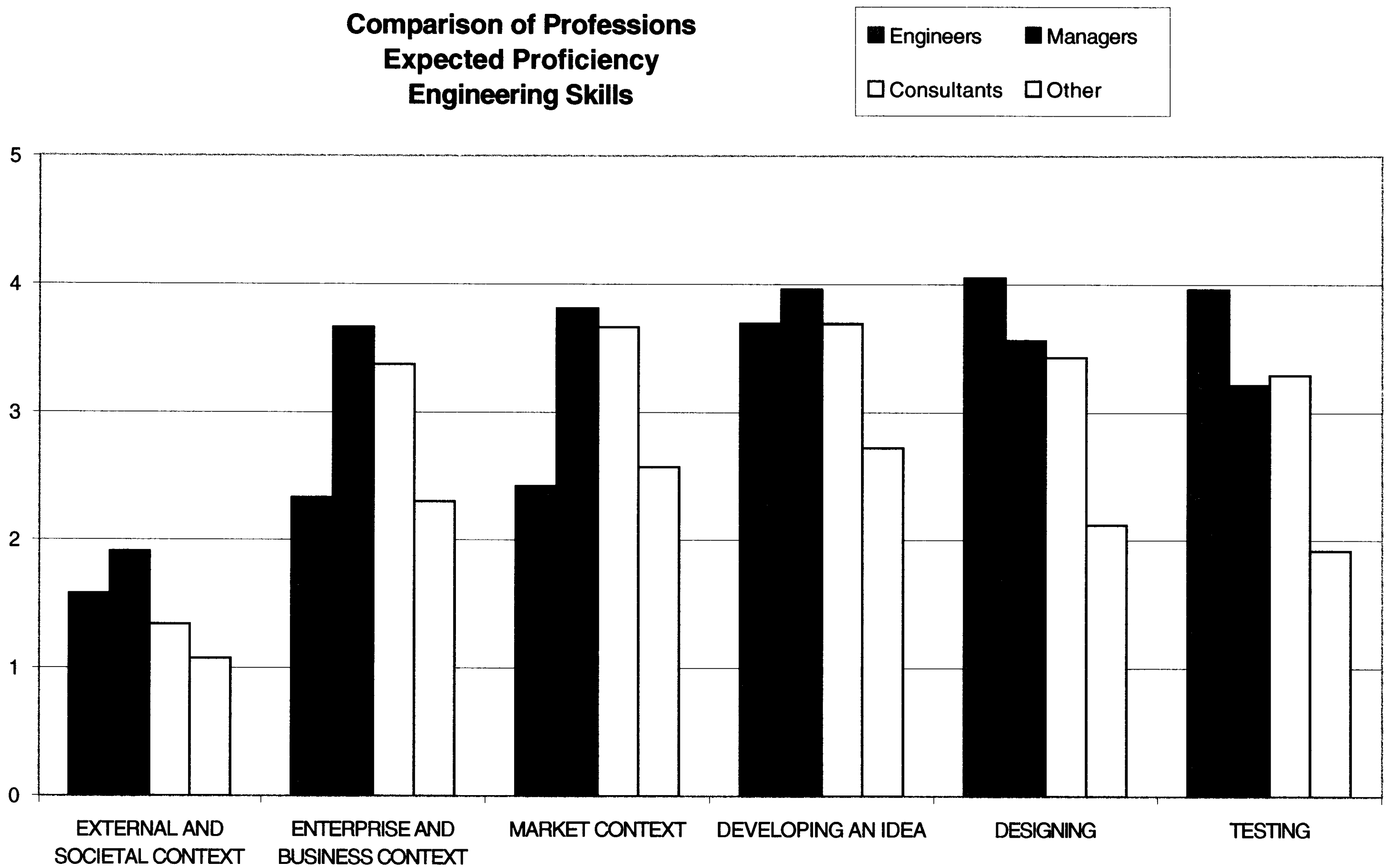


0 No knowledge of, 1 been exposed to, 2 participate in, 3 understand and explain, 4 skilled in the practice, 5 lead or innovate in

Comparison of Professions Expected Proficiency Interpersonal Skills



0 No knowledge of, 1 been exposed to, 2 participate in, 3 understand and explain, 4 skilled in the practice, 5 lead or innovate in



0 No knowledge of, 1 been exposed to, 2 participate in, 3 understand and explain, 4 skilled in the practice, 5 lead or innovate in

Another correlation considered was gender. The graduating classes of 1992 though 1996 in mechanical engineering were 75% male and 25% female. The respondents to the survey were 70% male and 30% female.

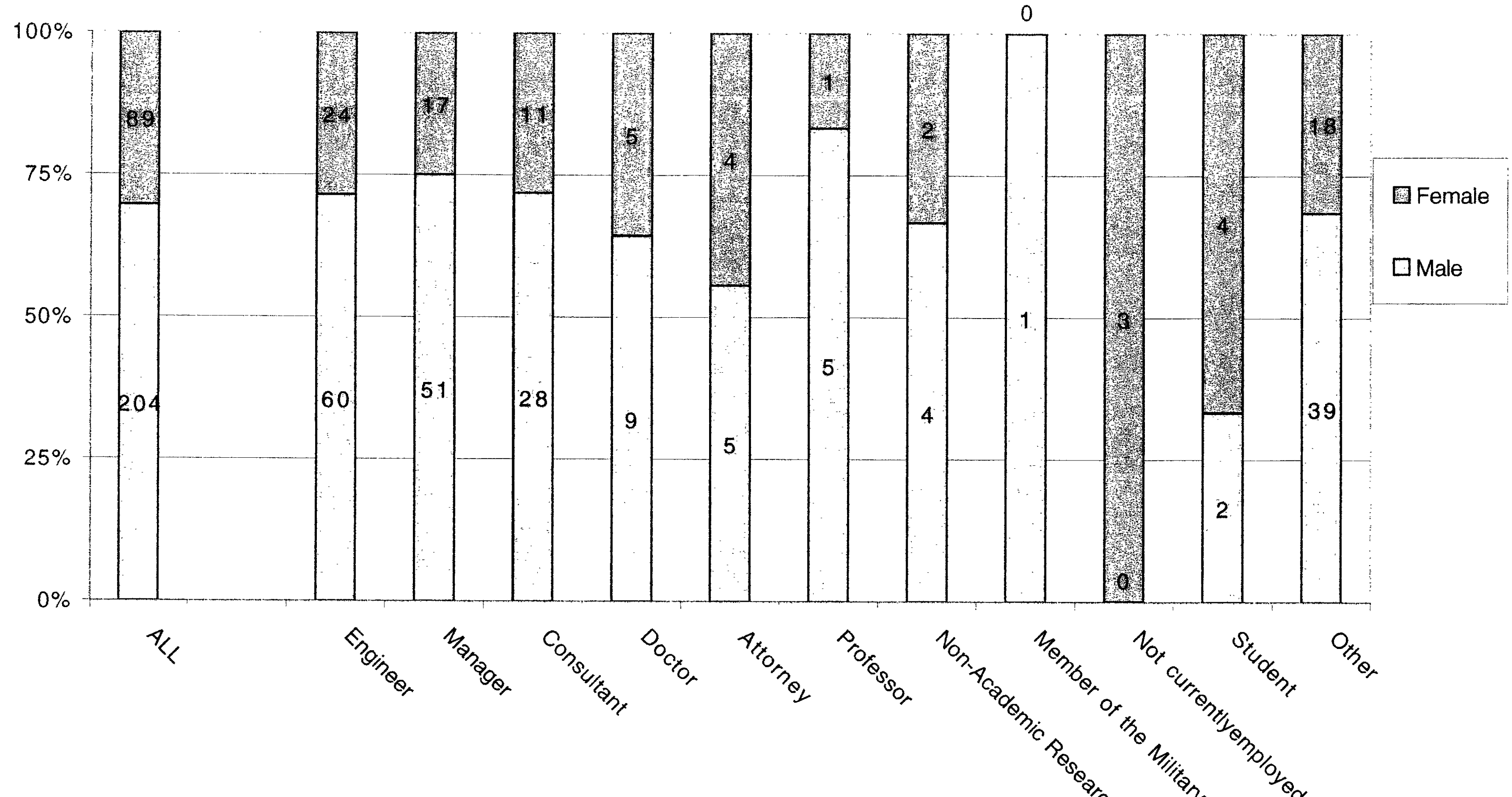
First I wanted to know the job distribution by gender. I used the "crosstabs" function in SPSS to determine this. The output is show below.

		Gender		Total
		Female	Male	
Job	Engineer	24	60	84
	Manager	17	51	68
	Consultant	11	28	39
	Doctor	5	9	14
	Attorney	4	5	9
	Professor	1	5	6
	Non-Academic Researcher	2	4	6
	Member of the Military	0	1	1
	Not employed outside the home	3	0	3
	Other	18	39	57
	Student	4	2	6
Total		89	204	293

I then used Excel to plot these results, which can be seen on the next page. It is interesting to note that most professions are split close to the 70/30 distribution of the respondents with the exception of member of the military, not employed outside the home, and student.

I considered differences in the responses for males and females. I used the same method described previously for profession. No significant variances were present. For further discussion of gender, see Appendix 8.

Job Distribution by Gender



Note: This chart is only for those responding to the survey.

The graduating classes of 1992 through 1996 are 75% Male and 25% Female.

Frequency:

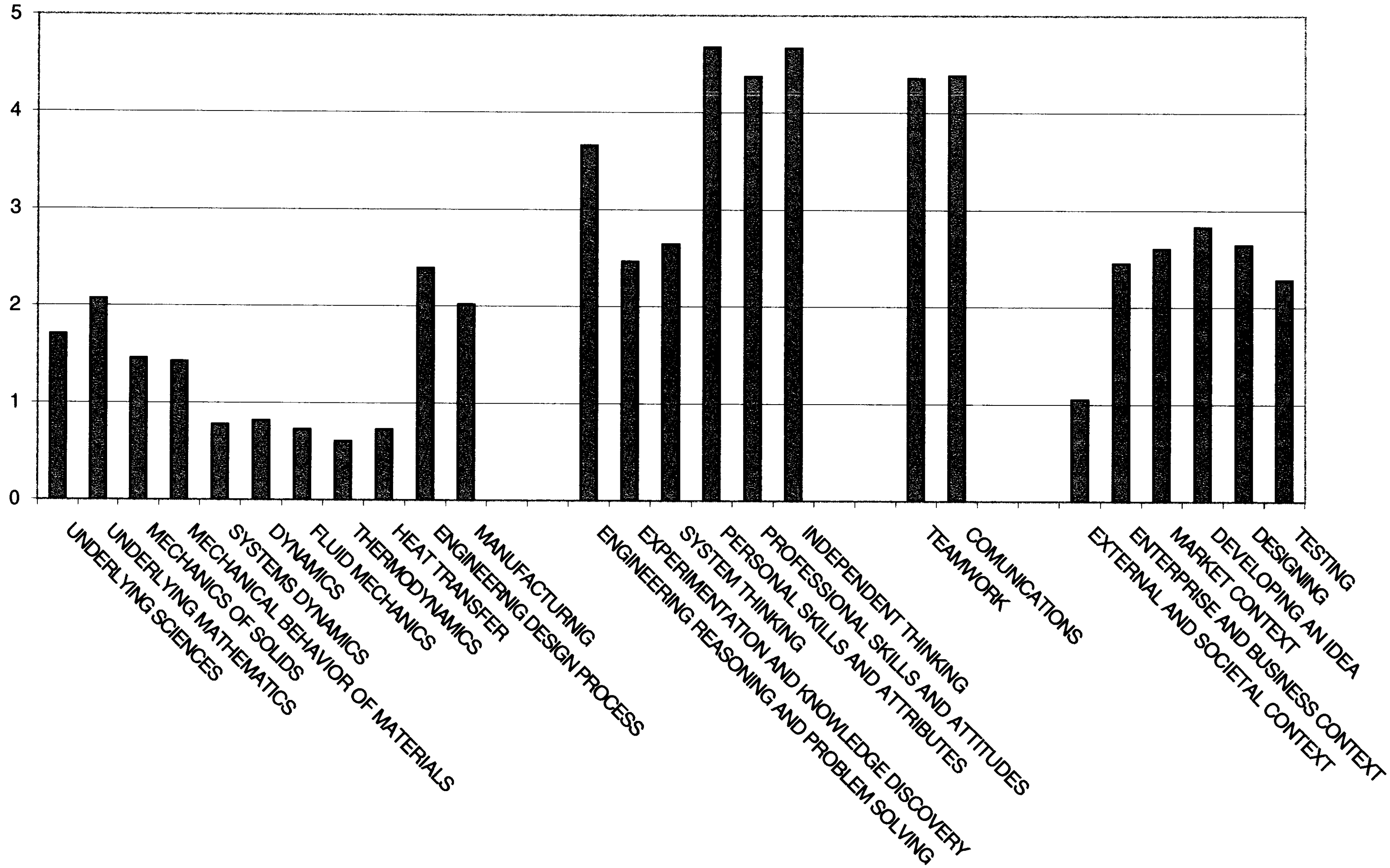
For each knowledge and skill area the graduates were asked to rate their frequency of use. The question was phrased as such:

> In your present position, how frequently do you employ the knowledge and skills from each of these areas?
>
> 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

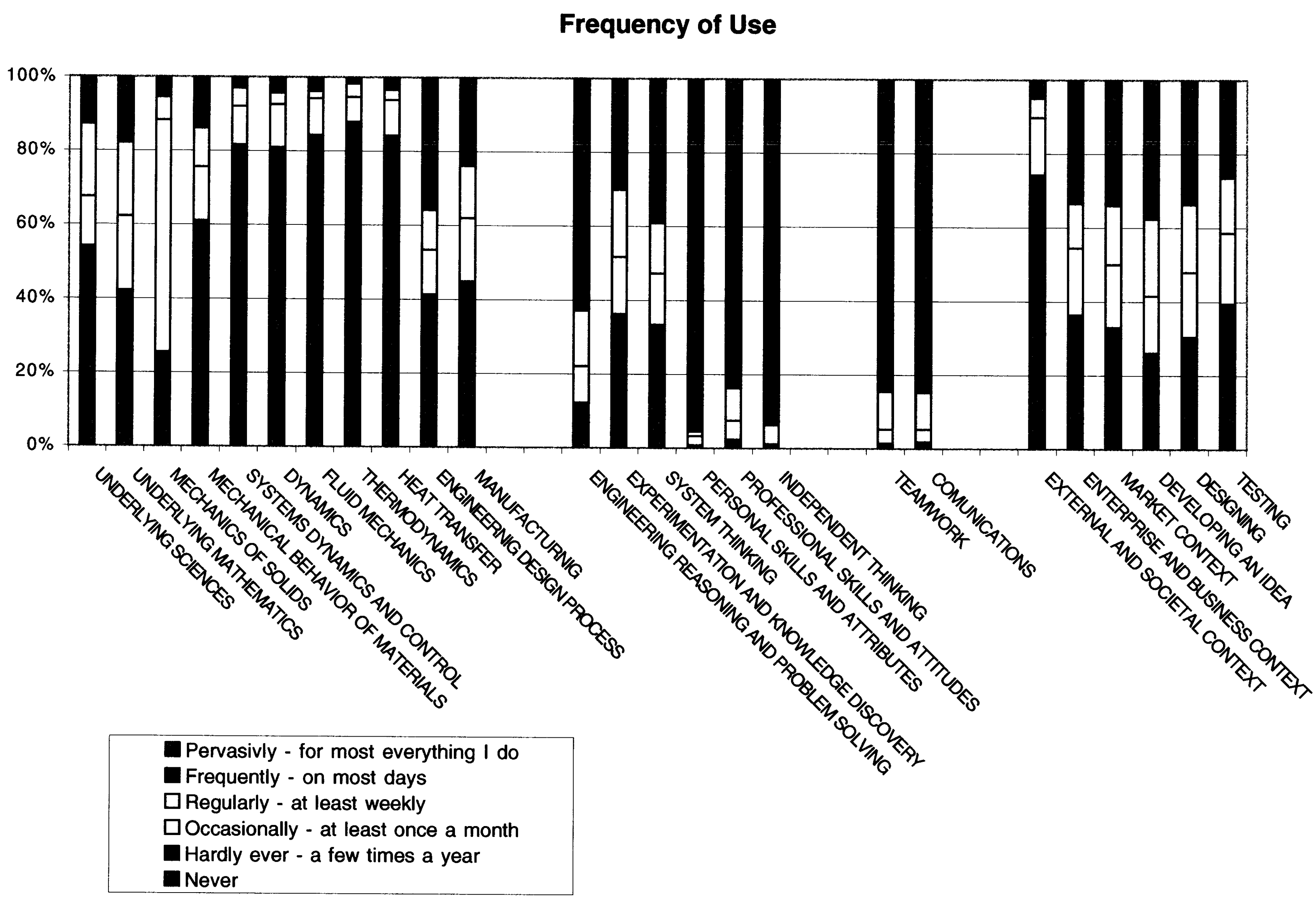
I conducted the same analysis as described before for proficiency. The results for frequency look very similar to that for proficiency, but are included here for completeness. Close to half of the respondents marked the same number for proficiency and frequency on any given area. Close to half marked either one number greater or one number smaller for any given area.

The next pages show the same charts for frequency as were discussed previously for proficiency.

Mean Frequency of Use

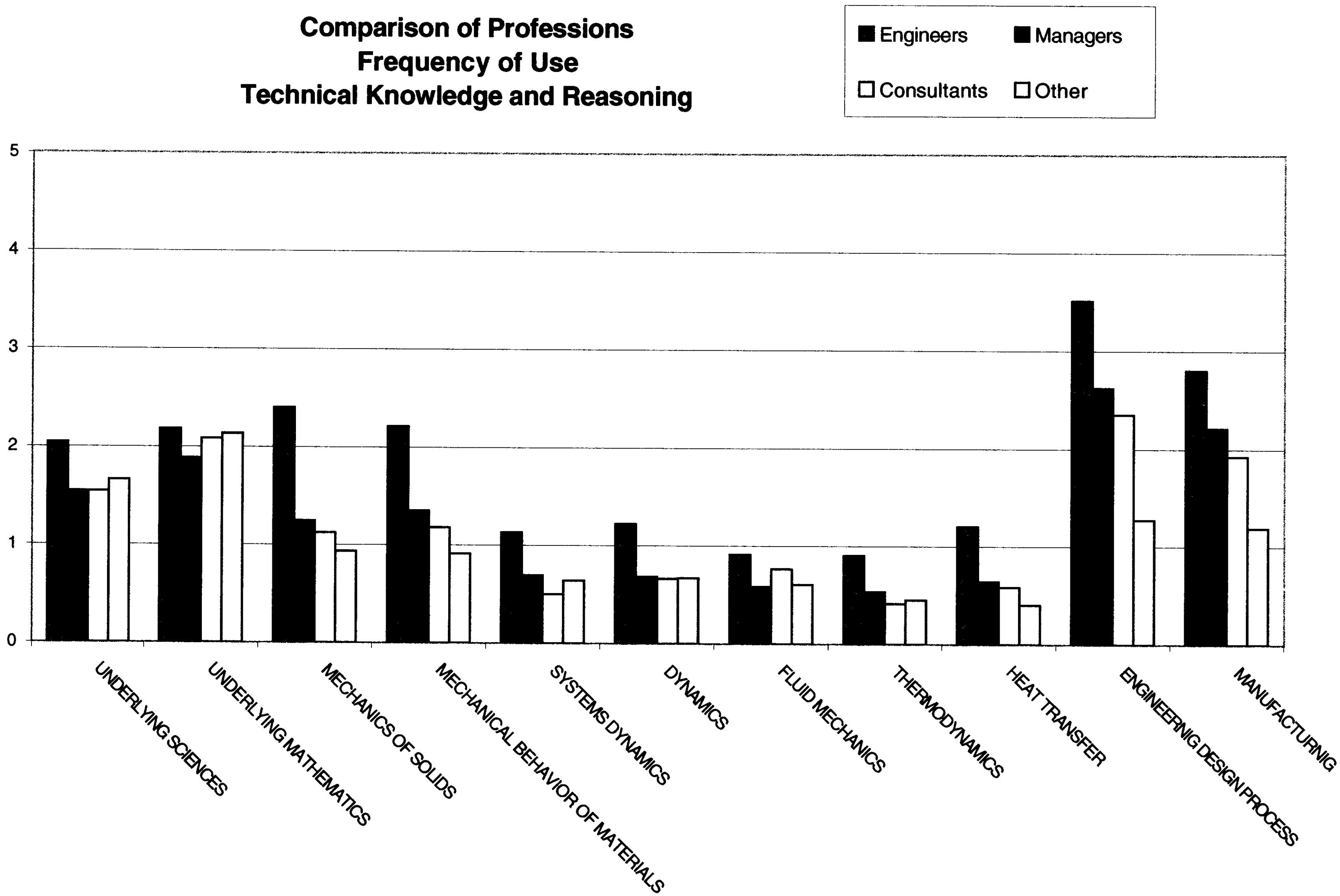


Frequency of Use: 0 Never, 1 Hardly ever - a few times a year, 2 Occasionally - at least once a month, 3 Regularly - at least weekly, 4 Frequently - on most days, 5 Pervasively - for most everything I do

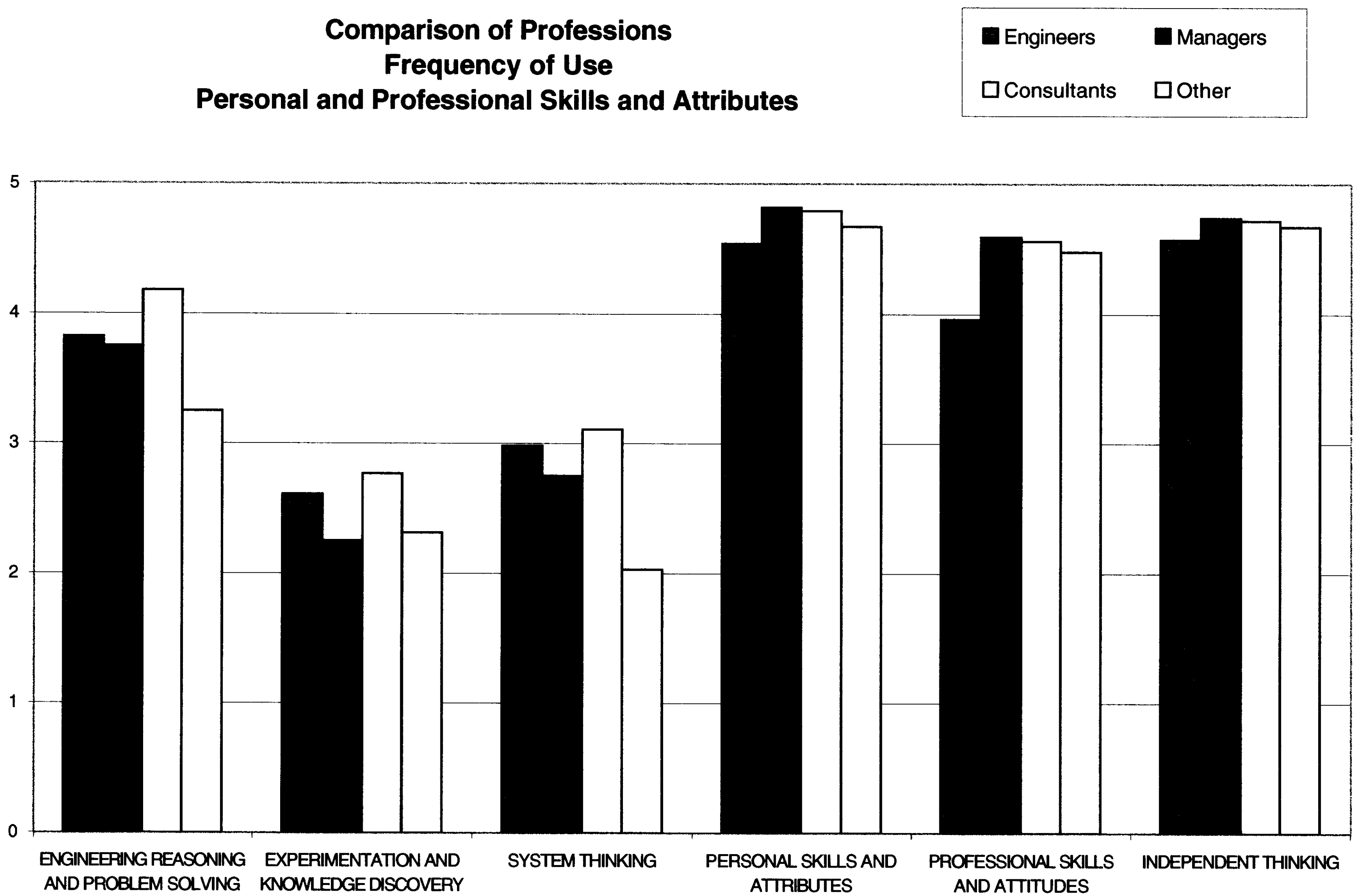


Frequency of Use
100%
80%
60%
40%
20%
0%
UNDERLYING SCIENCES
UNDERLYING MATHEMATICS
MECHANICS OF SOLIDS
MECHANICAL BEHAVIOR OF MATERIALS
SYSTEMS DYNAMICS AND CONTROL
DYNAMICS
FLUID MECHANICS
THERMODYNAMICS
HEAT TRANSFER
ENGINEERNIG DESIGN PROCESS
MANUFACTURNIG
ENGINEERING REASONING AND PROBLEM SOLVING
EXPERIMENTATION AND KNOWLEDGE DISCOVERY
SYSTEM THINKING
PERSONAL SKILLS AND ATTRIBUTES
PROFESSIONAL SKILLS AND ATTITUDES
INDEPENDENT THINKING
TEAMWORK
COMUNICATIONS
EXTERNAL AND SOCIETAL CONTEXT
ENTERPRISE AND BUSINESS CONTEXT
MARKET CONTEXT
DEVELOPING AN IDEA
DESIGNING
TESTING
Pervasivly - for most everything I do
Frequently - on most days
Regularly - at least weekly
Occasionally - at least once a month
Hardly ever - a few times a year
Never

Comparison of Professions
Frequency of Use
Technical Knowledge and Reasoning

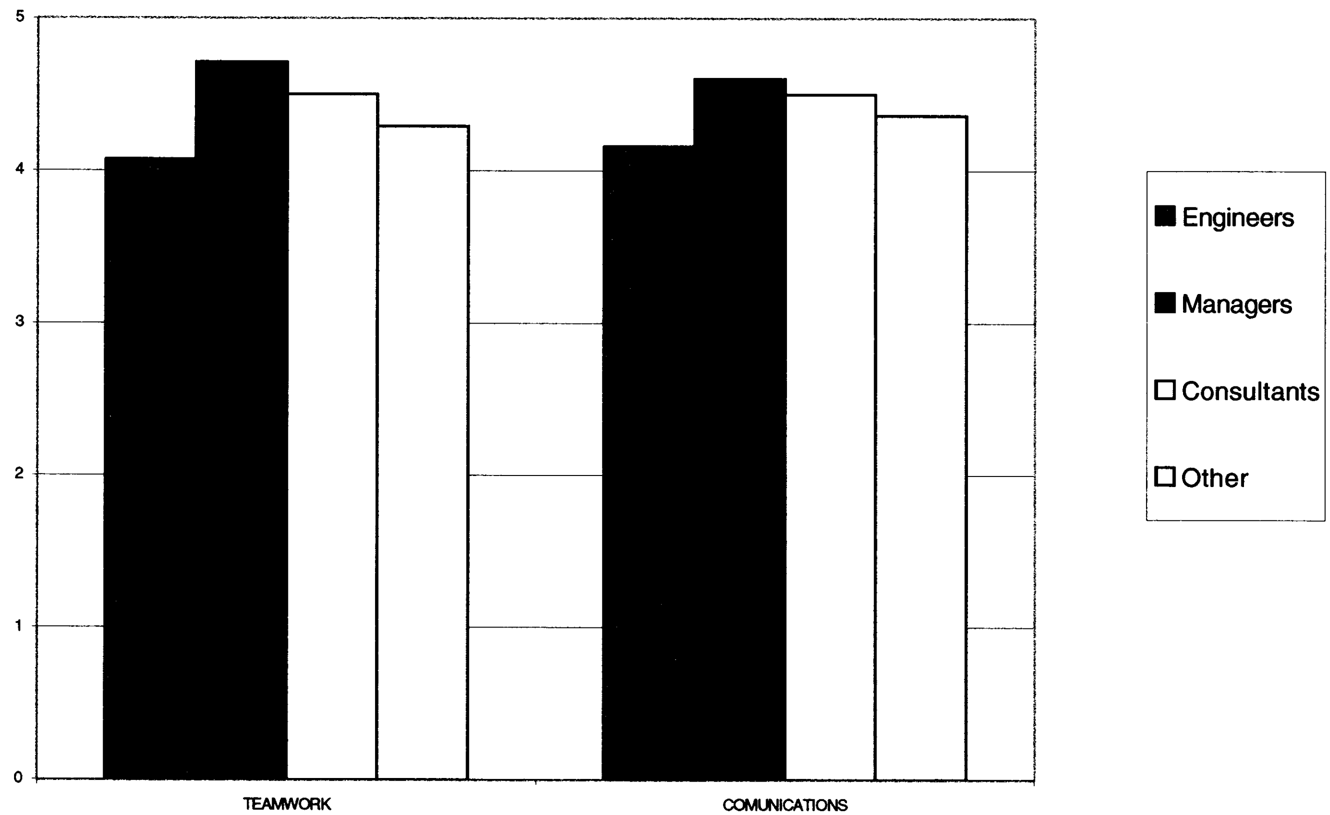


Frequency of Use: 0 Never, 1 Hardly ever, 2 Occasionally, 3 Regularly, 4 Frequently, 5 Pervasively

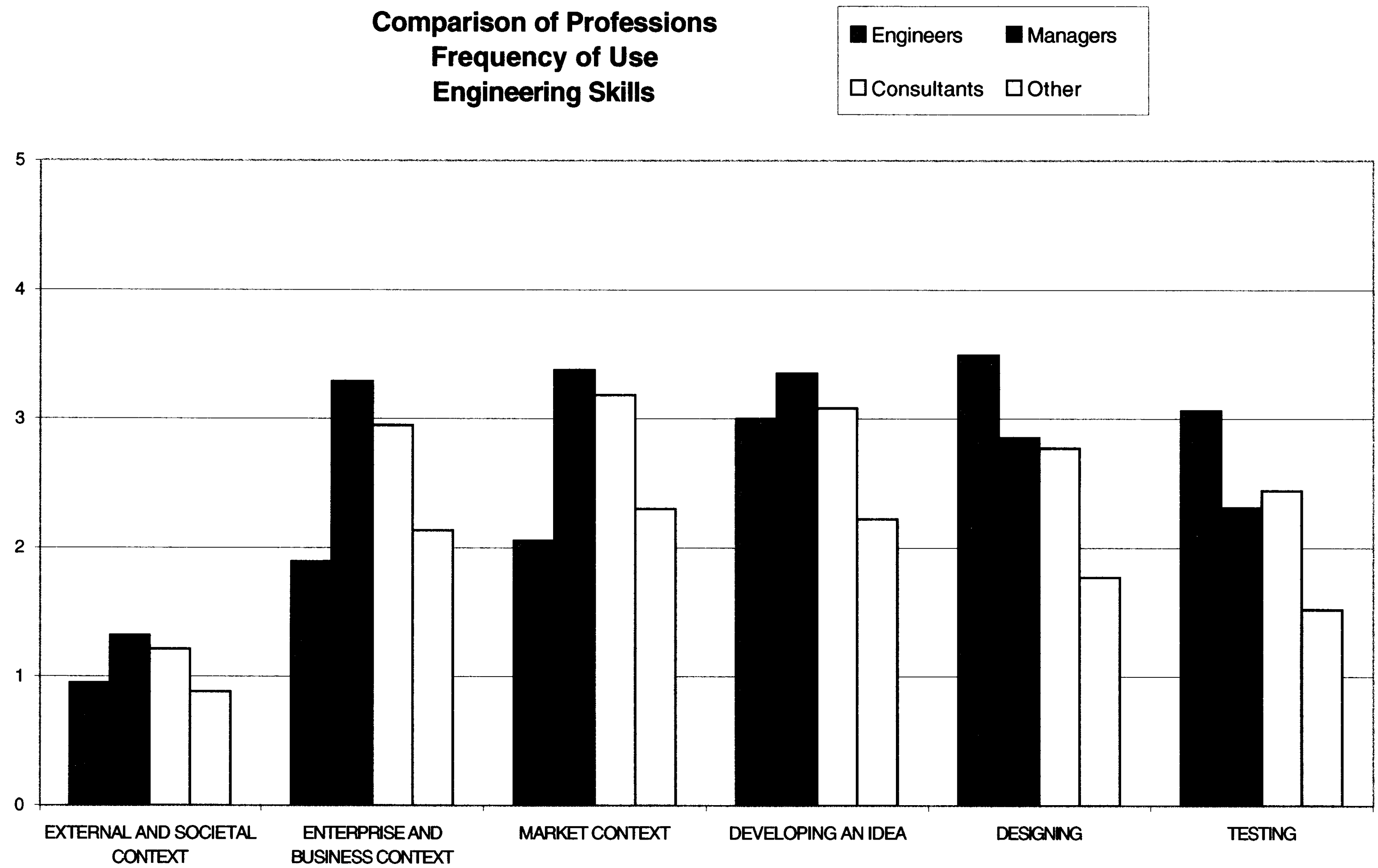


Frequency of Use: 0 Never, 1 Hardly ever, 2 Occasionally, 3 Regularly, 4 Frequently, 5 Pervasively

Comparison of Professions
Frequency of Use
Interpersonal Skills



Frequency of Use: 0 Never, 1 Hardly ever, 2 Occasionally, 3 Regularly, 4 Frequently, 5 Pervasively



Frequency of Use: 0 Never, 1 Hardly ever, 2 Occasionally, 3 Regularly, 4 Frequently, 5 Pervasively

Source:

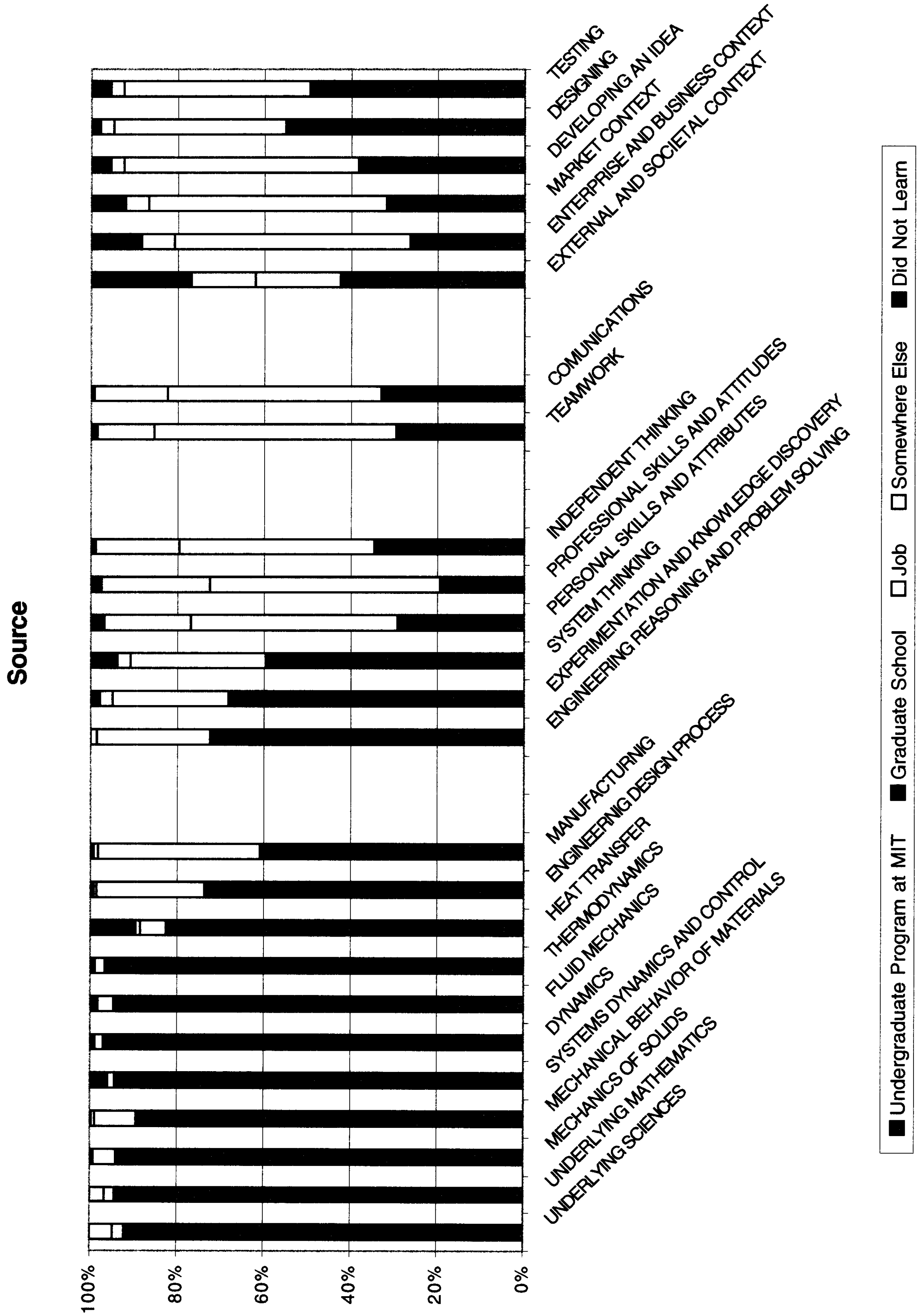
For each knowledge and skill area the graduates were asked to identify the primary source of their knowledge. The question was phrased as such:

> Where did you gain the most understanding about each topic?
>
> U – Undergraduate Program at MIT
> G – Graduate School
> J – Job
> E – Somewhere Else
> N – Did Not Learn

The method for analyzing this data was using the "frequency" function in SPSS to determine the number of respondents who answered each location for each area. I transferred these numbers to Excel to plot, as shown on the next page.

The areas most learned at MIT were the technical knowledge and reasoning areas contained in the core of the mechanical engineering curriculum, followed by engineering reasoning and problem solving.

Within this data I considered differences based on profession, graduating year and gender. No significant variances were present.



Source
100%
80%
60%
40%
20%
0%
TESTING
DESIGNING
DEVELOPING AN IDEA
MARKET CONTEXT
ENTERPRISE AND BUSINESS CONTEXT
EXTERNAL AND SOCIETAL CONTEXT
COMUNICATIONS
TEAMWORK
INDEPENDENT THINKING
PROFESSIONAL SKILLS AND ATTITUDES
PERSONAL SKILLS AND ATTRIBUTES
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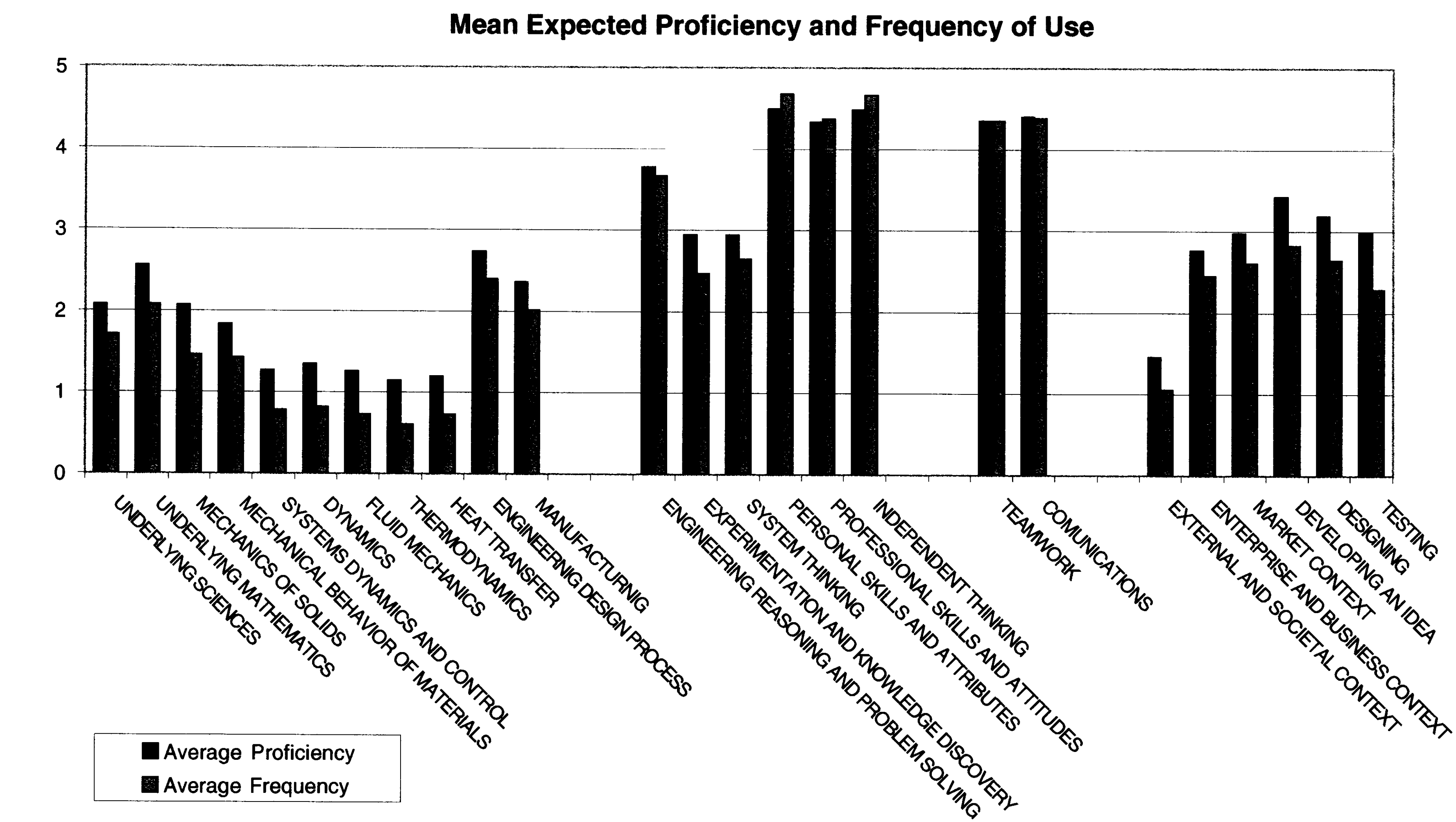
HEAT TRANSFER
THERMODYNAMICS
FLUID MECHANICS
DYNAMICS
SYSTEMS DYNAMICS AND CONTROL
MECHANICAL BEHAVIOR OF MATERIALS
MECHANICS OF SOLIDS
UNDERLYING MATHEMATICS
UNDERLYING SCIENCES
Undergraduate Program at MIT
Graduate School
Job
Somewhere Else
Did Not Learn

For more detail on the method of data manipulation and analysis presented in Chapters 3 and 4, see Appendix 9.

Chapter 5: Interpretation of Results and Conclusions

The data and charts presented in the previous chapter speak largely for themselves. I present them in this thesis as a stepping point for further discussion and research on the mechanical engineering curriculum. In this chapter I will offer my thoughts on the interpretation of the results, with the understanding that I am not an expert in the curriculum apart from my personal experiences as a student and my limited training in education.

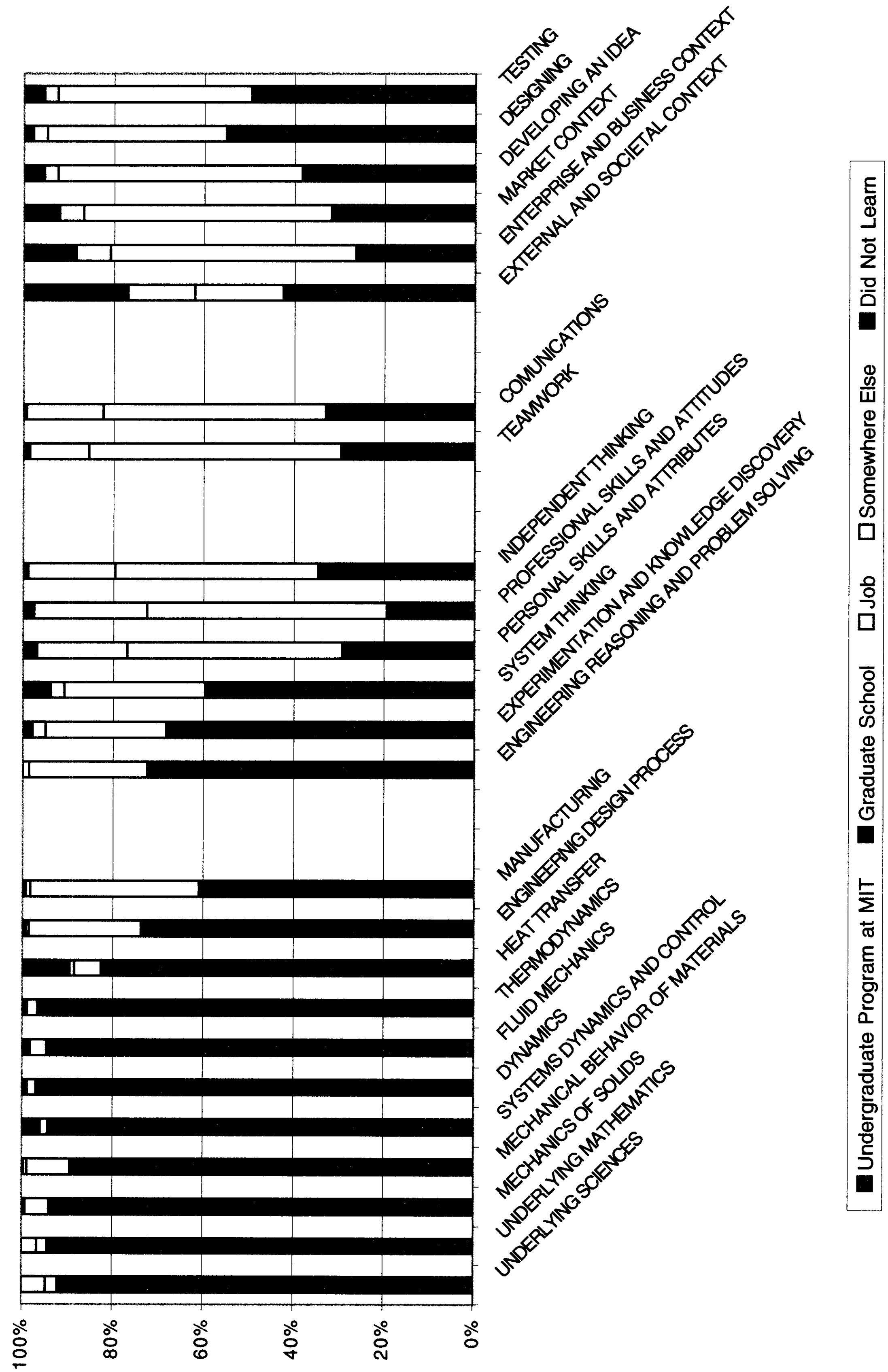
There are two charts that I believe deserve the most attention: average proficiency/frequency and source. These are replicated on the next pages for ease of reference with the discussion that follows.



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


100%
80%
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40%
20%
0%
TESTING
DESIGNING
DEVELOPING AN IDEA
MARKET CONTEXT
ENTERPRISE AND BUSINESS CONTEXT
EXTERNAL AND SOCIETAL CONTEXT
COMMUNICATIONS
TEAMWORK
INDEPENDENT THINKING
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PERSONAL SKILLS AND ATTRIBUTES
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HEAT TRANSFER
THERMODYNAMICS
FLUID MECHANICS
DYNAMICS
SYSTEMS DYNAMICS AND CONTROL
MECHANICAL BEHAVIOR OF MATERIALS
MECHANICS OF SOLIDS
UNDERLYING MATHEMATICS
UNDERLYING SCIENCES
Undergraduate Program at MIT
Graduate School
Job
Somewhere Else
Did Not Learn

One might hastily conclude in looking at these charts that there is little value in the core mechanical engineering courses because of their low levels of proficiency and frequency. However, as discussed before, this is an artifact of the specialization of the engineers at this stage in their careers. One might also hastily conclude the need to add classes to address the development of personal and profession skills, teamwork and communication. I do not believe this is the way to interpret the data or to achieve the desired outcome of better preparing our graduates.

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.

For the most part I believe professors assume the students will pick these up by virtue of the MIT experience. I propose there is a better way. For students to gain competence in these areas they need to be exposed to them and practice them regularly. I believe it requires a deliberate integration of these topics into the core curriculum. Currently, the written and oral communication aspects of course 2 are mainly through 2.671 and 2.672. I have not taken these classes, but have spoken with those who have. My concern is that this is an artificial environment. The students are learning how to communicate through fabricated experiments, which remain the same year after year. Communication is kept as an isolated component of the undergraduate education. I believe that a deliberate integration of personal skills, professional skills, independent thinking, teamwork and communication into each of the core engineering courses would serve the students much better. The difficulty comes in determining how best to integrate these areas into individual classes and the curriculum as a whole.

The structure of the core classes at this point makes any integration of such topics almost impossible. The core classes are already overflowing with their content knowledge and the work that accompanies it. There is little time for the students to process the knowledge and learn how to apply it with confidence. In order for change to occur, professors must recognize the downfalls of the "fire hydrant" approach and work to find the most effective way of enabling the students to learn. (Notice, I did not say the most effective way of teaching. I believe the job of a professor is to enable the students to learn. I think that this is very different from the commonly held view of what it is to teach.)

Conclusions:

Please accept these interpretations as my own. I am sure many will disagree with some or all of what I have said. I hope that the data I have compiled will be thought over carefully with much discussion. Making changes is never easy and determining the right changes to make is even harder. I leave this discussion to those who have made engineering education their career and are better equipped to recognize the changes that need to be made. Some may say that the curriculum is fine as it is because our alumni have accomplished so much in such a wide variety of professions. But I hope the department is never content with its program and is constantly striving for ways to make improvements so that MIT graduates will continue to go on to be leaders in all aspects of life.

Appendix 1: Catherine Kelly's Thesis

The following passages are excerpts from the introduction and conclusion of Catherine Kelly's thesis, "Some Trends in the Career Paths Followed by Alumni of the MIT Mechanical Engineering Department"

Introduction and Background

The general purpose of this research is to determine what career paths graduates of the MIT mechanical engineering department follow. In order to determine this, every fifth graduating class beginning in 1997 was examined. For each class, the occupations of the graduates were organized into a spreadsheet and then categorized. The information on each class' career paths was plotted and compared with the other classes. From this comparison, some conclusions were drawn about the general career patterns of the graduates. In total, 1665 graduates were studied and of these, 999 provided occupational information useful for this research.

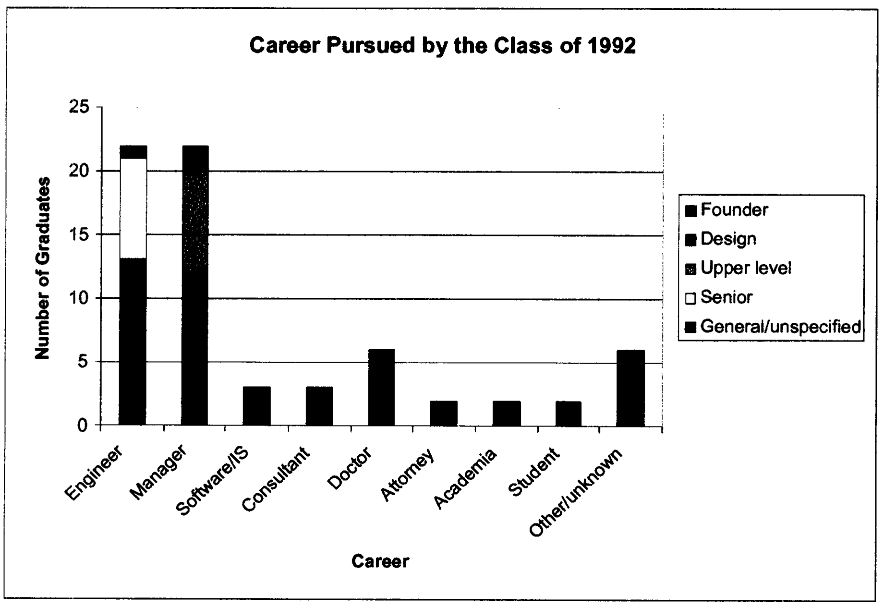
The impetus behind this research is to examine the career patterns in light of the courses offered by the mechanical engineering department. It can be argued that the mechanical engineering department should gear its courses to prepare the students for the peak of their careers. Students usually settle into their peak career approximately 10 years after graduation.

Catherine Kelly obtained information on the occupations of MIT graduates in cooperation with the MIT Alumni Association. They provided her with a list of alumni of each graduating class that included current occupation. She sorted the graduates by job category.

After going through a few classes of job sorting, I found that most classes have eight categories. The two largest are engineering and management. I divided these two categories into sub-categories since a few distinct ones seemed relevant to my work. Engineering was divided into general, design, and engineering management. I initially used senior engineering instead of engineering management but I decided that senior engineers were more in the general category where engineering managers were more of a distinct sub-category. Management was divided into general, upper level, and founder/self employed. These sub-categories are noted on the class bar charts, however, only the total engineering and management categories are noted in the final analysis and plot. The other smaller categories are: software/IS, consultant, attorney, doctor, academia, and other. The other category contains those graduates that have occupations that do not appear consistently such as fashion designer or elementary school teacher. During the more recent graduating classes, the category of student is also present. My reasoning for using these categories is that the seven specified categories appeared consistently over the graduating classes and the eighth category of other is allowed to contain those who do not fit in the other seven.

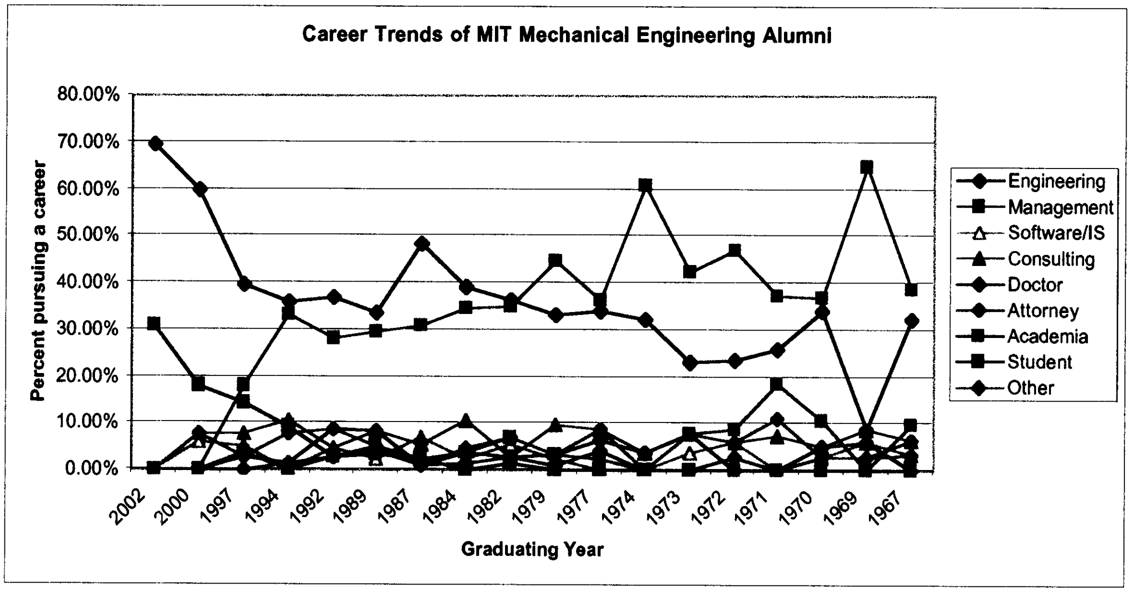
The final step of data analysis was to plot the results of the job sort. I did this by counting the number of graduates in a class in each occupational category and then using an Excel bar chart to plot the category totals all together. The bar charts of the different graduating classes were then compared and the changes in the relationships between the numbers of graduates in the various occupational categories were noted.

A sample bar graph for the class of 1992 can be seen below



Conclusions

The general trends found from this research are that most, approximately, two-thirds of MIT mechanical engineering graduates go into either engineering or management and that over the years the number of alumni in management increases while the number in engineering decreases. Over the years, the percentage of graduates in each occupation does fluctuate so the trend lines are not flat. Since enough data was studied in this research for a reasonable level of confidence in the results to be held, I feel that the trends still hold in spite of the fluctuation.



If it is assumed that the graduates reach their peak career around ten years after graduation, the data shows that by that point approximately one-third of the graduates are managers, one-third are engineers, and the remaining third are in a small variety of other occupations. This result could be interpreted in various ways by those looking for information on where MIT mechanical engineering graduates go after graduation and how to best prepare them. It could be viewed that since so many graduates do not stay in engineering, more coursework should be flexible to allow them to pursue their other interests. On the other hand, it could be said that since the graduated are already following on these career paths with the current coursework, no change is necessary.

As I am not an expert on course evaluation and planning, I will leave this matter to those better suited. The research to this point is a good beginning at determining what careers MIT mechanical engineering graduates pursue and how to best prepare them for these careers. However, there are some possible biases in the methods used in the research. Most notable are the occupations missing from the occupational categories. There are no unemployed nor are there any home makers/stay at home spouses. These occupations are likely held by some members of the classes studied. It is possible that the alumni with these occupations choose not to give information. This could imply that the results are "top heavy", meaning there is a larger percentage of higher prestige occupations, such as CEO or patent counsel, represented in the results than is true for the class. However, with the amount of data analyzed, I still feel the conclusions drawn are worthwhile. As with any research, more could still be done. A more accurate determination of actual career paths could be made by researching what careers particular alumni have held over the years. Also, more research could be done into careers pursued by women in the department versus men. This research provides a good general basis for any further work in this area

Appendix 2: The CDIO Syllabus

1 TECHNICAL KNOWLEDGE AND REASONING

1.1 KNOWLEDGE OF UNDERLYING SCIENCES

1.1.1 *Mathematics (including statistics)*
1.1.2 *Physics*
1.1.3 *Chemistry*
1.1.4 *Biology*

1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE

1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES

2.1 ENGINEERING REASONING AND PROBLEM SOLVING

2.1.1 *Problem Identification and Formulation*
- Data and symptoms
- Assumptions and sources of bias
- Issue prioritization in context of overall goals
- A plan of attack (incorporating model, analytical and numerical solutions, qualitative analysis, experimentation and consideration of uncertainty)

2.1.2 *Modeling*
- Assumptions to simplify complex systems and environment
- Conceptual and qualitative models
- Quantitative models and simulations

2.1.3 *Estimation and Qualitative Analysis*
- Orders of magnitude, bounds and trends
- Tests for consistency and errors (limits, units, etc.)
- The generalization of analytical solutions

2.1.4 *Analysis With Uncertainty*
- Incomplete and ambiguous information
- Probabilistic and statistical models of events and sequences
- Engineering cost-benefit and risk analysis
- Decision analysis
- Margins and reserves

2.1.5 *Solution and Recommendation*
- Problem solutions
- Essential results of solutions and test data
- Discrepancies in results
- Summary recommendations
- Possible improvements in the problem solving process

2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY

2.2.1 *Hypothesis Formulation*
- Critical questions to be examined
- Hypotheses to be tested
- Controls and control groups

2.2.2 *Survey of Print and Electronic Literature*
- The literature research strategy
- Information search and identification using library tools (on-line catalogs, databases, search engines)
- Sorting and classifying the primary information
- The quality and reliability of information
- The essentials and innovations contained in the information
- Research questions that are unanswered
- Citations to references

2.2.3 *Experimental Inquiry*
- The experimental concept and strategy
- The precautions when humans are used in experiments
- Experiment construction
- Test protocols and experimental procedures
- Experimental measurements
- Experimental data
- Experimental data vs. available models

2.2.4 *Hypothesis Test, and Defense*
- The statistical validity of data
- The limitations of data employed
- Conclusions, supported by data, needs and values
- Possible improvements in knowledge discovery process

2.3 SYSTEM THINKING

2.3.1 *Thinking Holistically*
- A system, its behavior, and its elements
- Trans-disciplinary approaches that ensure the system is understood from all relevant perspectives
- The societal, enterprise and technical context of the system
- The interactions external to the system, and the behavioral impact of the system

2.3.2 *Emergence and Interactions in Systems*
- The abstractions necessary to define and model system
- The behavioral and functional properties (intended and unintended), which emerge from the system
- The important interfaces among elements
- Evolutionary adaptation over time

2.3.3 *Prioritization and Focus*
- All factors relevant to the system in the whole
- The driving factors from among the whole
- Energy and resource allocations to resolve the driving issues

2.3.4 *Trade-offs, Judgment and Balance in Resolution*
- Tensions and factors to resolve through trade-offs
- Solutions that balance various factors, resolve tensions and optimize the system as a whole
- Flexible vs. optimal solutions over the system lifetime
- Possible improvements in the system thinking used

2.4 PERSONAL SKILLS AND ATTITUDES

2.4.1 *Initiative and Willingness to Take Risks*
- The needs and opportunities for initiative
- The potential benefits and risks of an action
- The methods and timing of project initiation
- Leadership in new endeavors, with a bias for appropriate action
- Definitive action, delivery of results and reporting on actions

2.4.2 *Perseverance and Flexibility*
- Self-confidence, enthusiasm, and passion
- The importance of hard work, intensity and attention to detail
- Adaptation to change
- A willingness and ability to work independently
- A willingness to work with others, and to consider and embrace various viewpoints
- An acceptance of criticism and positive response
- The balance between personal and professional life

2.4.3 *Creative Thinking*
- Conceptualization and abstraction
- Synthesis and generalization
- The process of invention
- The role of creativity in art, science, the humanities and technology

2.4.4 *Critical Thinking*
- The statement of the problem
- Logical arguments and solutions
- Supporting evidence
- Contradictory perspectives, theories and facts
- Logical fallacies
- Hypotheses and conclusions

2.4.5 *Awareness of One's Personal Knowledge, Skills and Attitudes*
- One's skills, interests, strengths, weaknesses
- The extent of one's abilities, and one's responsibility for self-improvement to overcome important weaknesses
- The importance of both depth and breadth of knowledge

2.4.6 *Curiosity and Lifelong Learning*
- The motivation for continued self-education
- The skills of self-education
- One's own learning style
- Developing relationships with mentors

2.4.7 *Time and Resource Management*
- Task prioritization
- The importance and/or urgency of tasks
- Efficient execution of tasks

2.5 PROFESSIONAL SKILLS AND ATTITUDES

2.5.1 *Professional Ethics, Integrity, Responsibility and Accountability*
- One's ethical standards and principles
- The courage to act on principle despite adversity
- The possibility of conflict between professionally ethical imperatives
- An understanding that it is acceptable to make mistakes, but that one must be accountable for them
- Proper allocation of credit to collaborators
- A commitment to service

2.5.2 *Professional Behavior*
- A professional bearing
- Professional courtesy
- International customs and norms of interpersonal contact

2.5.3 *Proactively Planning for One's Career*
- A personal vision for one's future
- Networks with professionals
- One's portfolio of professional skills

2.5.4 *Staying Current on World of Engineer*
- The potential impact of new scientific discoveries
- The social and technical impact of new technologies and innovations
- A familiarity with current practices/technology in engineering
- The links between engineering theory and practice

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION

3.1 TEAMWORK

3.1.1 *Forming Effective Teams*
- The stages of team formation and life cycle
- Task and team processes
- Team roles and responsibilities
- The goals, needs and characteristics (works styles, cultural differences) of individual team members
- The strengths and weakness of the team
- Ground rules on norms of team confidentiality, accountability and initiative

3.1.2 *Team Operation*
- Goals and agenda
- The planning and facilitation of effective meetings
- Team ground rules
- Effective communication (active listening, collaboration, providing and obtaining information)
- Positive and effective feedback
- The planning, scheduling and execution of a project
- Solutions to problems (team creativity and decision making)
- Conflict negotiation and resolution

3.1.3 *Team Growth and Evolution*
- Strategies for reflection, assessment, and self-assessment
- Skills for team maintenance and growth
- Skills for individual growth within the team
- Strategies for team communication and writing

3.1.4 *Leadership*
- Team goals and objectives
- Team process management
- Leadership and facilitation styles (directing, coaching, supporting, delegating)
- Approaches to motivation (incentives, example, recognition, etc)
- Representing the team to others
- Mentoring and counseling

3.1.5 *Technical Teaming*
- Working in different types of teams:
  - Cross-disciplinary teams (including non-engineer)
  - Small team vs. large team
  - Distance, distributed and electronic environments
- Technical collaboration with team members

3.2 COMMUNICATIONS

3.2.1 *Communications Strategy*
- The communication situation
  - Communications objectives
  - The needs and character of the audience
  - The communication context
- A communications strategy
  - The appropriate combination of media
  - A communication style (proposing, reviewing, collaborating, documenting, teaching)
  - The content and organization

3.2.2 *Communications Structure*
- Logical, persuasive arguments
  - The appropriate structure and relationship amongst ideas
  - Relevant, credible, accurate supporting evidence
  - Conciseness, crispness, precision and clarity of language
  - Rhetorical factors (e.g. audience bias)
- Cross-disciplinary cross-cultural communications

3.2.3 *Written Communication*
- Writing with coherence and flow
- Writing with correct spelling, punctuation and grammar
- Formatting the document
- Technical writing
- Various written styles (informal, formal memos, reports, etc)

3.2.4 *Electronic/Multimedia Communication*
- Preparing electronic presentations
- The norms associated with the use of e-mail, voice mail, and videoconferencing
- Various electronic styles (charts, web, etc)

3.2.5 *Graphical Communication*

Sketching and drawing
Construction of tables, graphs and charts
Formal technical drawings and renderings

3.2.6 *Oral Presentation and Inter-Personal Communications*

Preparing presentations and supporting media with appropriate language, style, timing and flow
Appropriate nonverbal communications (gestures, eye contact, poise)
Answering questions effectively

3.3 COMMUNICATIONS IN FOREIGN LANGUAGES

3.3.1 *English*
3.3.2 *Languages of Regional Industrialized Nations*
3.3.3 *Other Languages*

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT

4.1 EXTERNAL AND SOCIETAL CONTEXT

4.1.1 *Roles and Responsibility of Engineers*

The goals and roles of the engineering profession
The responsibilities of engineers to society

4.1.2 *The Impact of Engineering on Society*

The impact of engineering on the environment, social, knowledge and economic systems in modern culture

4.1.3 *Society's Regulation of Engineering*

The role of society and its agents to regulate engineering
The way in which legal and political systems regulate and influence engineering
How professional societies license and set standards
How intellectual property is created, utilized and defended

4.1.4 *The Historical and Cultural Context*

The diverse nature and history of human societies as well as their literary, philosophical, and artistic traditions
The discourse and analysis appropriate to the discussion of language, thought and values

4.1.5 *Contemporary Issues and Values*

The important contemporary political, social, legal and environmental issues and values
The process by which contemporary values are set, and one's role in these processes
The mechanisms for expansion and diffusion of knowledge

4.1.6 *Developing a Global Perspective*

The internationalization of human activity
The similarities and differences in the political, social, economic, business and technical norms of various cultures
International inter-enterprise and inter-governmental agreements and alliances

4.2 ENTERPRISE AND BUSINESS CONTEXT

4.2.1 *Appreciating Different Enterprise Cultures*

The differences in process, culture, and metrics of success in various enterprise cultures:

- Corporate vs. academic vs. governmental vs. non-profit/NGO
- Market vs. policy driven
- Large vs. small
- Centralized vs. distributed
- Research and development vs. operations
- Mature vs. growth phase vs. entrepreneurial
- Longer vs. faster development cycles
- With vs. without the participation of organized labor

4.2.2 *Enterprise Strategy, Goals, and Planning*
- The mission and scope of the enterprise
- An enterprise's core competence and markets
- The research and technology process
- Key alliances and supplier relations
- Financial and managerial goals and metrics
- Financial planning and control
- The stake-holders (owners, employees, customers, etc.)

4.2.3 *Technical Entrepreneurship*
- Entrepreneurial opportunities that can be addressed by technology
- Technologies that can create new products and systems
- Entrepreneurial finance and organization

4.2.4 *Working Successfully in Organizations*
- The function of management
- Various roles and responsibilities in an organization
- The roles of functional and program organizations
- Working effectively within hierarchy and organizations
- Change, dynamics and evolution in organizations

4.3 CONCEIVING AND ENGINEERING SYSTEMS

4.3.1 *Setting System Goals and Requirements*
- Market needs and opportunities
  - Customer needs
  - Opportunities that derive from new technology or latent needs
- Factors that set the context of the requirements
  - Enterprise goals, strategies, capabilities and alliances
  - Competitors and benchmarking information
  - Ethical, social, environmental, legal and regulatory influences
  - The probability of change in the factors that influence the system, its goals and resources available
- System goals and requirements
  - The language/format of goals and requirements
  - Initial target goals (based on needs, opportunities and other influences)
  - System performance metrics
  - Requirement completeness and consistency

4.3.2 *Defining Function, Concept and Architecture*
- Necessary system functions (and behavioral specifications)
- System concepts
- The appropriate level of technology
- Trade-offs among and recombination of concepts
- High level architectural form and structure
- The decomposition of form into elements, assignment of function to elements, and definition of interfaces

4.3.3 *Modeling of System and Ensuring Goals Can Be Met*
- Appropriate models of technical performance
- The concept of implementation and operations
- Life cycle value and costs (design, implementation, operations, opportunity, etc.)
- Trade-offs among various goals, function, concept and structure and iteration until convergence

4.3.4 *Development Project Management*
- Project control for cost, performance, and schedule
  - Appropriate transition points and reviews
  - Configuration management and documentation
  - Performance compared to baseline
- Earned value recognition
- The estimation and allocation of resources
- Risks and alternatives
- Possible development process improvements

4.4 DESIGNING

4.4.1 *The Design Process*

Requirements for each element or component derived from system level goals and requirements
Alternatives in design
The initial design
Experiment prototypes and test articles in design development
Appropriate optimization in the presence of constraints
Iteration until convergence
The final design
Accommodation of changing requirements

4.4.2 *The Design Process Phasing and Approaches*

The activities in the phases of system design (e.g. conceptual, preliminary, and detailed design)
Process models appropriate for particular development projects (waterfall, spiral, concurrent, etc.)
The process for single, platform and derivative products

4.4.3 *Utilization of Knowledge in Design*

Technical and scientific knowledge
Creative and critical thinking, and problem solving
Prior work in the field, standardization and reuse of designs (including reverse engineer and redesign)
Design knowledge capture

4.4.4 *Disciplinary Design*

Appropriate techniques, tools, and processes
Design tool calibration and validation
Quantitative analysis of alternatives
Modeling, simulation and test
Analytical refinement of the design

4.4.5 *Multidisciplinary Design*

Interactions between disciplines
Dissimilar conventions and assumptions
Differences in the maturity of disciplinary models
Multidisciplinary design environments
Multidisciplinary design

4.4.6 *Multi-Objective Design (DFX)*

Design for:

- Performance, life cycle cost and value
- Aesthetics and human factors
- Implementation, verification, test and environmental sustainability
- Operations
- Maintainability, reliability, and safety
- Robustness, evolution, product improvement and retirement

4.5 IMPLEMENTING

4.5.1 *Designing the Implementation Process*

The goals and metrics for implementation performance, cost and quality
The implementation system design:

- Task allocation and cell/unit layout
- Workflow
- Considerations for human user/operators

4.5.2 *Hardware Manufacturing Process*

The manufacturing of parts
The assembly of parts into larger constructs
Tolerances, variability, key characteristics and statistical process control

4.5.3 *Software Implementing Process*
- The break down of high-level components into module designs (including algorithms and data structures)
- Algorithms (data structures, control flow, data flow)
- The programming language
- The low-level design (coding)
- The system build

4.5.4 *Hardware Software Integration*
- The integration of software in electronic hardware (size of processor, communications, etc)
- The integration of software with sensor, actuators and mechanical hardware
- Hardware/software function and safety

4.5.5 *Test, Verification, Validation, and Certification*
- Test and analysis procedures (hardware vs. software, acceptance vs. qualification)
- The verification of performance to system requirements
- The validation of performance to customer needs
- The certification to standards

4.5.6 *Implementation Management*
- The organization and structure for implementation
- Sourcing, partnering, and supply chains
- Control of implementation cost, performance and schedule
- Quality and safety assurance
- Possible implementation process improvements

4.6 OPERATING

4.6.1 *Designing and Optimizing Operations*
- The goals and metrics for operational performance, cost, and value
- Operations process architecture and development
- Operations (and mission) analysis and modeling

4.6.2 *Training and Operations*
- Training for professional operations:
  - Simulation
  - Instruction and programs
  - Procedures
- Education for consumer operation
- Operations processes
- Operations process interactions

4.6.3 *Supporting the System Lifecycle*
- Maintenance and logistics
- Lifecycle performance and reliability
- Lifecycle value and costs
- Feedback to facilitate system improvement

4.6.4 *System Improvement and Evolution*
- Pre-planned product improvement
- Improvements based on needs observed in operation
- Evolutionary system upgrades
- Contingency improvements/solutions resulting from operational necessity

4.6.5 *Disposal and Life-End Issues*
- The end of useful life
- Disposal options
- Residual value at life-end
- Environmental considerations for disposal

4.6.6 *Operations Management*
- The organization and structure for operations
- Partnerships and alliances
- Control of operations cost, performance and scheduling
- Quality and safety assurance
- Possible operations process improvements
- Life cycle management

Appendix 3: CDIO Survey

This is the survey used by Prof. Crawley to determine the expected proficiency levels for each topic in the syllabus. Note that section 1 is not included in this version of the survey. Prof. Crawley's reasoning was that sections 2 through 4 "arguably contain the topics for which outside opinion is most useful in establishing expected levels of competence" [10].

	Circle one level of proficiency for each topic				
	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

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES

2.1 ENGINEERING REASONING AND PROBLEM SOLVING *Problem Identification and Formulation* *Modeling* *Estimation and Qualitative Analysis* *Analysis With Uncertainty* *Solution and Recommendation*	1	2	3	4	5
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY *Hypothesis Formulation* *Survey of Print and Electronic Literature* *Experimental Inquiry* *Hypothesis Test, and Defense*	1	2	3	4	5
2.3 SYSTEM THINKING *Thinking Holistically* *Emergence and Interactions in Systems* *Prioritization and Focus* *Trade-offs and Balance in Resolution*	1	2	3	4	5
2.4 PERSONAL SKILLS AND ATTRIBUTES *Initiative and Willingness to Take Risks* *Perseverance and Flexibility* *Creative Thinking* *Critical Thinking* *Awareness of One's Personal Knowledge, Skills and Attitudes* *Curiosity and Lifelong Learning* *Time and Resource Management*	1	2	3	4	5
2.5 PROFESSIONAL SKILLS AND ATTITUDES *Professional Ethics, Integrity, Responsibility and Accountability* *Professional Behavior* *Proactively Planning for One's Career* *Staying Current on World of Engineer*	1	2	3	4	5

3 Communication

3.1 TEAMWORK *Forming Effective Teams* *Team Operation* *Team Growth and Evolution* *Leadership* *Technical Teaming*	1	2	3	4	5
3.2 COMMUNICATIONS *Communications Strategy* *Communications Structure* *Written Communication* *Electronic/Multimedia Communication* *Graphical Communication* *Oral Presentation and Inter-Personal Communications*	1	2	3	4	5

4 OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT

4.1 EXTERNAL AND SOCIETAL CONTEXT *Roles and Responsibility of Engineers* *The Impact of Engineering on Society* *Society's Regulation of Engineering* *The Historical and Cultural Context* *Contemporary Issues and Values* *Developing a Global Perspective*	1	2	3	4	5
4.2 ENTERPRISE AND BUSINESS CONTEXT *Appreciating Different Enterprise Cultures* *Enterprise Strategy, Goals, and Planning* *Technical Entrepreneurship* *Working Successfully in Organizations*	1	2	3	4	5
4.3 CONCEIVING AND ENGINEERING SYSTEMS *Setting System Goals and Requirements* *Defining Function, Concept and Architecture* *Modeling of System and Insuring Goals Can Be Met* *Development Project Management*	1	2	3	4	5
4.4 DESIGNING *The Design Process* *The Design Process Phasing and Approaches* *Utilization of Knowledge in Design* *Disciplinary Design* *Multidisciplinary Design* *Multi-Objective Design (DFX)*	1	2	3	4	5
4.5 IMPLEMENTING *Designing the Implementation Process* *Hardware Manufacturing Process* *Software Implementing Process* *Hardware Software Integration* *Test, Verification, Validation, and Certification* *Implementation Management*	1	2	3	4	5
4.6 OPERATING *Designing and Optimizing Operations* *Training and Operations* *Supporting the System Lifecycle* *System Improvement and Evolution* *Disposal and Life-End Issues* *Operations Management*	1	2	3	4	5

Appendix 4: Engineering Council: SARTOR

Roles and Responsibilities of Chartered Engineers

Section Extracted: Competence and Commitment of Chartered Engineers

Competence	A	Knowledge and Understanding
	B	Application to Practice
	C	Leadership and Management
	D	Interpersonal Skills
Commitment	E	Professional Conduct

Chartered Engineers are competent, by virtue of their initial formation and throughout their working life, to:

A. Use a combination of general and specialist engineering knowledge and understanding to optimise the application of existing and emerging technology. *This includes an ability to:*

A.1 maintain a sound theoretical approach in enabling the introduction of new and advancing technology and other relevant developments;

A.2 apply a creative problem solving approach;

A.3 look for ways of exploiting emerging technologies to enhance current practices and to ensure continuing fitness for purpose of engineered products and services;

A.4 promote innovation and technology transfer.

B. Apply appropriate theoretical and practical methods to the analysis and solution of engineering problems. *This includes an ability to:*

B.1 identify potential projects and opportunities;

B.2. conduct appropriate research, and undertake design and development of possible solutions;

B.3 plan and implement solutions, taking a holistic approach to cost, benefits, safety, quality, reliability, appearance and environmental impact;

B.4 evaluate the solutions and make improvements.

C. Provide technical, commercial and managerial leadership. *This includes an ability to:*

C.1 plan for effective project implementation;

C.2 plan, budget, organise, direct and control tasks, people and resources;

C.3 develop the capabilities of staff to meet the demands of changing technical and managerial requirements;

C.4 bring about continuous improvement through quality management.

D. Use effective communication and interpersonal skills. *This includes an ability to:*

D.1 work and communicate with others at all levels;

D.2 effectively present and discuss ideas and plans;

D.3 build teams and negotiate.

E. Make a personal commitment to live by the appropriate code of professional conduct, recognising obligations to society, the profession and the environment. *In order to satisfy this commitment, they must:*

E.1 comply with the Codes and Rules of Conduct;

E.2 manage and apply safe systems of work;

E.3 undertake their engineering work in compliance with the Codes of Practice on Risk and the Environment;

E.4 carry out the continuing professional development necessary to ensure competence in their areas of future intended practice.

Taken from: SARTOR 3rd Edition, Document 2.1.1
Published by the Engineering Council
June 23, 1998

The Educational Base for Chartered Engineers

Section Extracted: <u>Course Content, Structure and Balance</u>

Knowledge of -

- The engineering, physical and biological sciences which underpin a **range** of engineering disciplines. This breadth of knowledge will be a foundation for learning within the particular degree discipline and prepare graduates for work in inter-disciplinary teams.
- The in-depth requirements within the discipline of the particular degree.
- The methods of providing information for use by others within engineering.
- A wide range of tools, techniques and equipment, including the computer software pertinent to the engineering discipline.

An Understanding of -

- Mathematics as a method of communicating results, concepts, and ideas.
- The principles on which the discipline of the particular degree is based.
- Methods of applying engineering principles to create products, systems and services.
- Constraints in applying technology to create products, systems and services.
- Engineering design methods and their applications.

The Ability to -

- Be creative and innovative.
- Use mathematics as a tool for solving complex problems.
- Use laboratory and workshop equipment to generate valuable data.
- Evaluate and derive information from data to produce useful results.
- Communicate effectively with clients, colleagues and public.
- Use IT effectively.

- Manage projects, people, resources and time.
- Work in a multi-disciplinary team.
- Solve problems of a non-routine nature.

An Awareness of -

- Quality systems and management in engineering.
- Requirements and responsibilities of leadership
- Obligations to work safely and to apply safe systems of work
- Risk analysis.
- The financial, economic, social and environmental factors of significance to engineering.
- The relevant legal, statutory and contractual obligations.
- The broader obligations of engineers to society.

Taken from: SARTOR 3rd Edition, Document 4.1.1
Published by the Engineering Council
September 11, 1997

Appendix 5: Correspondence

Initial Email:

Dear Graduate,

My name is Kristen Wolfe and I am a senior at MIT in the Mechanical Engineering Department. I am currently working on my thesis project with Professor Warren Seering. I am contacting you in regards to this project in the hope that you might be willing to help. We want to understand more clearly what skills our graduates make use of in their professions. Our vision and mission for this research are as follows:

VISION: The mechanical engineering curriculum will prepare our graduates to be leaders in their chosen professions. By leaders we mean the people in a given profession who are highly regarded by their peers and other professional colleagues.

MISSION: We will learn about the professional activities of our graduates in order to discern what specifically they do in their jobs, and then use that information to tailor our curriculum to reflect the needs of our alumni.

You can help to accomplish this by filling out our survey from

http://linktosurvey.com
(This is a unique link, assigned only to you, so please do not share it with others or forward this email to others.)

The survey should take you about 15 to 20 minutes to complete. Your response is greatly appreciated.

Thank you for your time and input,
Kristen Wolfe - MIT Class of '04

Follow-up Email from Kristen:

Dear Graduate,

About a week ago you received an email asking for your participation in the Mechanical Engineering Alumni Survey. If you have just 15 minutes, please complete the survey. Regardless of your current occupation, your response is valuable to me in writing my senior thesis and to the entire mechanical engineering department as we work to improve the curriculum. We know that our graduates go on to pursue a wide variety of career paths and we are interested in understanding what all our graduates do.

http://linktosurvey.com
(This is a unique link, assigned only to you, so please do not share it with others or forward this email to others.)

Thank you, Kristen Wolfe - MIT Class of '04

Follow-up Email from Prof. Seering

Dear Mechanical Engineering graduates,

As you know if you've stayed in touch with news from the Institute, we are about to undertake the first Institute-wide curriculum upgrade in decades (since before you were born, in fact). It is our ongoing intent to offer our undergraduates the best preparation we can for the lives that they will choose to lead. That's where we need your help.

At times in the past we've asked our recent graduates for feedback about our course requirements. But we've never before methodically surveyed our graduates after they've had a chance to explore job options and, with some years of perspective, choose career and life paths. In the last three weeks we've learned a great deal about the choices that our graduates make and about the consequent expectations that they face. This information is extremely valuable to us as we consider what and how we teach. We think you might find it interesting as well, and we're pleased to have a chance to share it with you.

We are most grateful to those of you who have taken the time to respond to Kristen Wolfe's survey. We're told that it takes about 15 minutes. We know now that the first of the five pages is pretty dense, but the subsequent ones are significantly less so. And each page is yielding valuable insights about what success demands of our alumni. The thesis deadline is approaching rapidly; Kristen will have to stop collecting data in a week or so. (After graduation, she is headed to Cleveland to teach physics in an inner-city school there, another of the many ways that our graduates put their degrees to work.)

Please take the time, if you have not done so already, to respond to the web survey request that we sent to you a few weeks ago. Then, if you are interested, indicate on the last page that you would like to receive a summary of the survey results. We will send them your way shortly after the thesis due date has passed.

With best regards,

Warren Seering
Weber-Shaughness Professor of Mechanical Engineering

Hard Copy Version of Survey:

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
UNDERLYING SCIENCES *Physics; Chemistry; Biology*			
UNDERLYING MATHEMATICS *Calculus; Linear Algebra; Differential Equations; Statistics*			
MECHANICS OF SOLIDS *Force and Moment Equilibrium; Conditions of Geometric Fit; Material Behavior*			
MECHANICAL BEHAVIOR OF MATERIALS *Elasticity, Fracture, Fatigue, Plasticity, Friction, Wear, Corrosion; Use of Materials in Mechanical Design*			
SYSTEMS DYNAMICS *Dynamic Modeling and Response; System Functions, Pole-Zeros, and Their Interpretation*			
DYNAMICS *Kinematics and Dynamics of Bodies in Motion; Behavior of Linearized Models: Natural Modes and Frequency Response, Wave Transmission and Reflection*			
FLUID MECHANICS *Incompressible Flows; Equations of Fluid Motion*			
THERMODYNAMICS *1^{st} and 2^{nd} Laws; Pure Substance Models*			
ENGINEERNIG DESIGN PROCESS *Concept generation; Detail design; Machine elements; Scheduling of Design Activities; Prototype Testing*			
MANUFACTURNIG *Manufacturing Processes; Systems; Equipment*			

2 PERSONAL AND PROFESSIONAL SKLLS AND ATTRIBUTES	Proficiency 0-5	Frequency 0-5	Source U,G,J,E,N
2.1 ENGINEERING REASONING AND PROBLEM SOLVING *Problem Identification and Formulation; Modeling; Estimation and Quantitative Analysis; Analysis With Uncertainty; Solution and Recommendation; Understanding Causal Relationships*			
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY *Hypothesis Formulation; Survey of Print and Electronic Literature; Experimental Inquiry; Hypothesis Test and Defense*			
2.3 SYSTEM THINKING *Defining the System; Understanding the System/Environment Interface; Defining Sub-systems; Emergence and Interactions in Systems; Prioritization and Focus*			
2.4 PERSONAL SKILLS AND ATTRIBUTES *Initiative and Willingness to Take Risks; Perseverance and Flexibility; Creative Thinking; Critical Thinking; Awareness of One's Personal Knowledge, Skills and Attitudes; Time and Resource Management*			
2.5 PROFESSIONAL SKILLS AND ATTITUDES *Professional Ethics, Integrity, Responsibility and Accountability; Professional Behavior; Proactively Planning for One's Career; Continuous Learning*			
2.6 INDEPENDENT THINKING *Skills in Working Independently; Skills in Setting Project Goals; Ability to Extract and Evaluate Relevant Knowledge from Various Sources; Confidence in Own Skills and Abilities*			

3 INTERPERSONAL SKILLS	Proficiency 0-5	Frequency 0-5	Source U,G,J,E,N
3.1 TEAMWORK *Goal Setting; Scheduling; Leadership; Effective Teamwork*			
3.2 COMMUNICATIONS *Written Communication; Electronic/Multimedia Communication; Graphical Communication; Oral Presentation; Inter-Personal Communications; Communication of Information to Those Outside the Field*			

4 ENGINEERING SKILLS	Proficiency 0-5	Frequency 0-5	Source U,G,J,E,N
4.1 EXTERNAL AND SOCIETAL CONTEXT *Roles and Responsibility of Engineers; The Impact of Engineering on Society; Society's Regulation of Engineering; The Historical and Cultural Context; Developing a Global Perspective*			
4.2 ENTERPRISE AND BUSINESS CONTEXT *Appreciating Different Enterprise Cultures; Enterprise Strategy, Goals, and Planning; Technical Entrepreneurship; Working Successfully in Organizations*			
4.3 MARKET CONTEXT *Understanding Market Opportunities; Customer Needs and Preferences; Financial Planning for New Products*			
4.4 DEVELOPING AN IDEA *Setting System Goals and Requirements; Defining Product Function; Modeling of System; Insuring Goals Can Be Met*			
4.5 DESIGNING *The Design Process; Conceptual Design; Making Trade-offs; Detail Design*			
4.6 TESTING *Building a Prototype; Test, Verification; Validation*			

The following are occupations that our graduates commonly choose. Please check the box that most closely describes your current occupation.

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

So far we have been asking about specific knowledge and skills. We now want to open up to a broader scope. What were the most meaningful aspects of your MIT experience for you? (List up to 3):

Appendix 6: The Most Meaningful Aspects of the MIT Experience

At the very end of the survey, graduates were posed the following question: So far we have been asking about specific knowledge and skills. We now want to open up to a broader scope. What were the most meaningful aspects of your MIT experience for you? (List up to 3):

About half of the respondents chose to answer and what they said is recorded on the next few pages. Their responses have been broken down into general categories: academics, activities, people and other. Within academics, the responses are broken down into the subcategories of problem solving and general.

In addition to answering the question posed, some people used the section to indicate things they would have liked added to the curriculum. Their comments and suggestions are also provided at end.

Note: these are direct quotes from the respondents. Spelling errors have been corrected.

Academics:

– Problem Solving

Learning how to learn. Learning how to think systematically and to solve problems analytically. Also stretching myself to excel in both the classroom and athletics (crew). I think that going through any kinds of rigorous courses that require mental discipline and advanced, logical problem solving is beneficial. Frankly the soft courses, such as engineering ethics, were not very valuable. The core courses such as 2.01, 2.02, etc did teach basic, analytical problem solving and rigor which is valuable in any field.

The general skills problem solving, how to define it, set it up, consider alternatives, test hypotheses, and come to some reasonable and logical conclusion or decision. Also confidence that if I applied myself (not always the case) that I could compete with highly intelligent and motivated peers

Most meaningful was the learning and practicing the process of analysis and design to problems. In my current field of software engineering, details of mechanical system are not used as all, but, the approach to problem solving, systems analysis and interactions, and to some extent, team dynamics have been most useful.

Learning to think and analyze problems and situations - Have a broad experience and set of skills in many engineering subjects
Developing independent, problem-solving skills through challenging coursework and research through the Mechanical Engineering and Biology Departments. Also, the excellent, albeit underrated Humanities Department that provided balance to a heavy science and technology oriented workload.

Develop problem-solving skill. Operations and manufacturing courses where we actually operated equipment and CAD/CAM tools. Economics courses. I work for startup technology companies setting up marketing channels and sales teams so the actual engineering information is only useful in understanding products we may be dealing with. Great general technology foundation. I also did course 2A so opted out of some core classes. Will be going to business school in September... MIT did also provide credibility and background when working with technology and technical people.

(1) Learning to work under pressure / high workloads (2) Learning how to decompose, model, analyze, and solve problems in a general sense

The experience in solving problems, quantitatively and/or qualitatively, has been the most meaningful.

Training in how to solve a problem of any scope or discipline (I feel that MIT teaches a process, which is of great value, versus specifics, which are limiting/limited)

1. Analytical approach to problem solving. This skill is very important for both developing new designs and for troubleshooting existing designs (such as during testing or fieldwork instances). 2. Teamwork/Communication Skills. MIT provided me a good foundation in these skills thru the numerous group (small and large) projects/presentations and the technical writing requirement. Typically, a multidisciplinary team that communicates and interacts effectively is required to solve most workplace challenges.

More than the minutia of Mechanical Engineering, MIT taught me how to tackle difficult problems systematically. It is this approach to problem solving and the resulting resourcefulness that I have been forced to acquire that has helped me the most in my career. I don't have to necessarily know everything (or most things). More important is that I know where to get the answers I don't have and how to then use those answers and other information/resources to solve the relevant problems at hand. The pressure and competition at MIT honed my resourcefulness and gave me the swift kick in the derriere that I (unfortunately) too often need to get things done. I regret that I didn't retain as much of the info as I feel I should have from the fire hydrant that is MIT's undergraduate experience, nor did I take full advantage of things like UROP and other MIT opportunities. Still, successfully having emerged, I can always draw on my MIT experience--- the workforce, relatively speaking is not so tough--- to get me out of tight situations I find myself in (work-wise or otherwise).

How to think about approaching and solving any problem

I learned about problem solving. Law school was engineering with words rather than numbers.

Problem solving skills (MIT Education). Ability to translate technical / science information into business /layman terms (95% of population) -combination of MIT experiences. Time management (double majored in course 2 and 7). Dealing with failure in everyday life and career / job - essential in real world (was not a straight A student at MIT)

I think the very rigorous technical and theoretical education provided an important foundation. Longer lasting, though, were probably the strong problem solving skills and striving for excellence that were instilled in me there. I think this makes sense since most people change careers at least once in their lives. For me, the mechanical engineering courses that I took aren't directly relevant to my current work (I currently do software and digital imaging engineering), but the other skills that I learned in my MIT experience (problem solving, striving for excellence) have helped define and guide my career.

The most valuable skill I gained while at MIT was the ability to learn through creative problem solving under almost any circumstances.
Additionally, MIT helped prepare me to work cooperatively with others (although that preparation seemed unique to Courses 2 and 4).

Not necessarily the specific skills (e.g. how to solve a DiffEq problem), but the general method of how to "approach" any problem (e.g. what is known/unknown, what are the assumptions, what is the goal that you're trying to obtain, where can you find the information you need, etc.)

By far the most beneficial skill I learned while at MIT is how to think critically of a problem and solve it. I use critical thinking on a daily basis in everything that I do. I apply it in different forms, but it all comes down to identifying a situation, breaking it down into subsets and identifying solutions to address the various subsets within the overall situation.

Having a broad range of activities and opportunities to expand or deepen understanding. Also, receiving an education that emphasizes creative thought and problem solving abilities.

Further developing my critical thinking skills.

– General

A sense of accomplishment from completion of hands-on projects (still talk/reflect about some projects in courses 2 and 13). Understanding motivation on a personal level (since there was not a lot of hand-holding at MIT).

Learning technical material in really hard classes with other smart people who were as interested in learning "geeky" stuff as I was.

1) Quick response to difficult problems 2) Relaying complex ideas to managers in simplistic form 3) Attention to engineering detail

The technical grounding from the MIT education has served me very well. It's not the specific details, but a way of looking at the world. I have moved into a more creative field, and the engineering base is critical to my success.

The UROP program was also a big part of my education, allowing me to get early hands-on experience. Plus, the EIP (engineering internship program) was a huge benefit for getting summer jobs and "real-world" exposure. In any case, it wasn't until grad school that I was forced to exercise independent thinking, which is very important now.

Brand name and recognition of institution and degree program; Broad educational experience that allows graduates the flexibility to easily go into a variety of fields

I finally "learned to learn' at MIT. Suddenly I knew I could pick up a new topic or subject and, with the right level of effort, begin to understand and use the material. I've already been successful in two distinct career paths. I expect to continue to learn and develop for the rest of my life.

My 3 UROP's were the most meaningful aspects of my academic MIT experience. They gave me opportunities to put into practice mechanical engineering concepts that I learned in the classroom, to participate in real-world projects, and exposure to other fields that I later pursued (computer science).

Fire hose learning technique- helps you process large quantities of information and adapt quickly to the real world.

1) Learning how to educate yourself in a new field is incredibly important, and is the most valuable skill gained from an MIT education. 2) Understanding the non-technical and social aspects of how to get scientific work done was a key discovery while at MIT. [e.g. In general, 80% of problems aren't technical; they're people problems. Also, MIT and the work place are not pure meritocracies. They're political.] 3) Deep knowledge in particular fields is very helpful. It's important to get beyond superficial functionality and rote in subjects.

All-encompassing project management, design and research experience during graduate school (MS & PhD) with Prof. Chun, from leadership to system development to organization, etc.

Breadth of exposure, and sometimes depth, although what helps me more is the broadness of my exposure, to be a little fish in a larger pond as opposed to a big fish in a smaller pond -- it 'fixes' the ego, and it enriches the mind.

Design and fabrication - bearings lecture was amazing fatigue and materials for my current job - system dynamics - feedback is especially important

1) UROP experiences 2) Bachelors and Masters Thesis

Industry related projects like the ones with GM. UROP (I think that's what it was)... Undergraduate Research Opportunity Program? Basically summer work opportunities. Undergraduate Thesis... really where I got my programming and chosen career related skills

The Reynolds Transport Theorem -- 18.01, 18.02, 18.03, 8.01, 8.022, 2.01, 2.02, 2.20, 2.30, 2.40, 2.51, 6.071, 13.81 all teach the same thing -- how to use rules for "closed systems" to deal with the "open systems" of the real world. "Take care of your free body diagram and your free body diagram will take care of you" is really the same as "what goes in, either comes out, or stays in."

- Planning to meet and meeting deadlines (problem sets, papers, exams, etc.) - Interacting in a structured environment (class, lab, social settings, etc.) - Conversing with multi-cultural and highly intellectual people -Working in teams (labs, design classes, etc.) - Setting a research plan and producing a deliverable (thesis)

Theoretical to practical - Sometimes I feel the link could have been made more explicit, but overall, MIT offered a good overview of how the theories you're learning are used in industry. Technical vigor - Being able to recognize, model, analyze, and debug physical and organizational systems quickly is a huge competitive advantage in the workplace.

The system dynamics aspects of our curriculum were invaluable, and I took that thinking with me, and I apply it to every single aspect of my personal and professional life. I don't know that other schools teach that so pervasively.

1. Work ethic (working hard, doing a complete job, value of smart/motivated teammates) 2. Strong theoretical basis for engineering (since we can learn the practical aspects in doing a thesis in grad school or on the job) 3. Practical ways to apply the theoretical knowledge (UROPs, Solar Car Team, 2.009, 2.72, 2.744, 2.007, Grad Thesis)

1. One of the most meaningful aspects of my MIT Engineering education was the fact that the scope of learning was very broad, very general, focusing mainly on understanding physical principles, not learning a specific set of skills for a particular job. My MIT education provided me with the ability to think and to learn, on my own, whatever new skills are required in my professional career. 2. Another meaningful part of my MIT experience was the design class 2.70. That course gave me a taste for doing design which I could not shake even after two years of graduate study in system dynamics and controls. I am now a design engineer, and I like to describe my job in the following way "I get paid to take my favorite class from college, only the box of parts is a lot bigger".

1. Manufacturing engineering - designed and manufactured plastic yo-yo's, learned to use mills and lathes 2. Senior Product Design class work, including market surveys, concept design, prototype construction. 3. Fluids Lab - matching theory to physical experiments

Activities:

Interpersonal skills from dorm living/ski team/intramurals (or not becoming a singularly focused individual only on class work). All of these help me to recognize/resolve problems with the people who work for me and with me as well as retaining a focus on the common goal (whatever is defined/expected).

At MIT, I always felt if there was something I wanted to do or try, the Institute would help me do that. The variety of opportunities available at MIT is the best thing about being there: sports, extracurricular activities, IAP, living in a frat.

Social maturity and confidence gained through living in an off-campus fraternity

My active participation with SHPE-MIT provided me with experience, exposure and confidence with leadership skills I use today.

Dormitory life -- the sense of community, of sharing, of being with lots of other smart people, of cooking together.

Communication and leadership skills (very active on MIT Debate Team)

Through extracurricular activities (e.g. varsity sports), understanding that I need balance in my life between work and play.

People:

Social aspect of being away from home and "growing up" / becoming more independent and exposed to a wider array of people and ideas

To be perfectly honest, the network of friends was the most important thing. These people have served as my sounding boards and mentors throughout my careers, as well as being an excellent resource for new jobs/career changes when I needed them.

Honing interpersonal skills and meeting people from many different cultures which is essential in today's business world

From both undergrad and grad at MIT, I think a very valuable benefit was the relationships that I made with my peers and my professors. I've relied on them for job placement and career guidance.

People I met and relationships I developed have benefited me over the years

Lasting interpersonal relationships (friends, colleagues, professors, etc.)

Meeting a great group of fellow students regardless of their major - some of the best people that I know.

The design curriculum was life changing! The meaningful aspects are the professors I had the chance to interact with. Woodie Flowers Harry West Ernest Blanco Because of them I have embarked on a lifelong journey of researching, practicing, and teaching design. My thanks to them all.

Developing friendships with some of the brightest people I've ever met - regardless of occupation.

Global focus- diversity of students helps you break down barriers and understand the big picture.

The lasting life-long friendships that I've made, both at the undergrad and graduate level.

Meeting and interacting with people so much smarter than me from all around the world and the long-lasting friendships with others subjected to the same torture

1. Benchmarking - observing some of the most talented and motivated people in the world showed me what one can accomplish and to this day drives me to improve myself and accomplish more than I otherwise would 2. Diversity - getting exposed to people of different backgrounds opened my mind to new ideas that continue to help me see the world from a broader perspective 3. People Acumen

- observing students' behaviors and how those behaviors were perceived by others taught me a lot about human nature and helped me improve the way I interact with people

Going to school with really smart people (I have great confidence in my abilities now, i.e.: If I can make it at MIT, I can make it anywhere. I also have good humility in that I know that there are people out there who are far more intelligent than I am.)

People I met (lifelong friends, inspirations, networking contacts, "support" group, etc)

Making enduring, lifelong friendships and exposure to students from all over the United States and the world

Collaborative Environment - I had the most fun and learned the most when there were plenty of other people going through the same thing.

Being exceptionally intelligent can make a person feel very lonely; MIT helped me realize that while I may be rare, I'm not out there, and there are other people like me-- it also made me much less tolerant of "average" people

The most meaningful aspect of my time at MIT was working with the professors, either as an undergraduate UROP, Bachelor's Thesis student, or Graduate Research Assistant or Teaching Assistant. I also have to say that teaching was a very rewarding experience. I enjoyed working with the undergraduates and at the same time it helped me obtain better clarity of the material. The say if you really know a subject, you can teach it. Well here is the corollary: If you want to teach a subject you better know it! Teaching also helped develop my interpersonal skills.

Finding a community of intellectual and creative individuals and creating friendships with some of them; specifically, meeting the woman that would become my wife!

Other:

Thinking on your feet. Developing rigor. Being faced with very tough challenges and figuring out a game plan with limited constraints - usually time.

Understanding my limitations BUT more importantly how smart/innovative I really was. Being crushed by humiliation but learning at an early intellectual stage to get back up and show em what I'm made of.

1) Competition - being surrounded by other very intelligent people.

This challenged me to do my best. 2) Creativity - in high school, being different made others look down upon you. At MIT it meant that you were more creative and intelligent and you were challenged to do this.

Competitive environment- gives you an edge in career and knowledge growth.

The content of the actual classes I took are not the thing that
I carry with me on a daily basis. I would say that the process of how to work effectively and efficiently while learning something new, and at the same time balancing multiple responsibilities (classes, fraternity, teams), is the most useful skill that attending MIT forced me to develop.

I think the most relevant things MIT gave me were discipline & self-confidence.

Never, ever being overwhelmed or "scared" of anything the professional world has thrown at me. After MIT, anything seems do-able. Also, the 'expectation' of excellence that comes with the degree from MIT. Employer's and peers expect great things from MIT graduates, and those 3 letters have opened many, many doors for me.

Managing time pressures, priorities, constraints, people among a large variety of choices

Learning how much sleep I need -- 8 hours per night. Too little and I will go insane, and not work up to my standards.

Learning to be confident in my own abilities, especially technically (i.e., I can hold my own in this area, and I don't have to be intimidated by smart people). The ability to learn anything, and learn it rapidly. And, I have used this frequently in job interviews -- my MIT degree shows that I can learn anything and learn it quickly.

Understanding how far I can push myself, the extreme limits of what I can accomplish under pressure, and under what conditions I work best.

Most Meaningful was the balance of engineering academics with sports (team based activities) and research experience (thesis)

1. Personal growth: learning to live away from home, meeting such diverse and talented people, exposure to other cultures. 2. Availability of resources: being able to do almost all you might want to do if you put your heart to it 3. Quality of faculty: it is inspiring to have such high caliber teachers and be able to have them as resources when you are just an undergraduate

Comments/Suggestions for Improvement
(Note: these are not answers to a specific question; rather they are the thoughts that certain respondents expressed in lieu of or in addition to the question discussed previously)

Weakest part of MIT education: Lack of exposure to actual engineering practice. Initially (first few years) I was at a disadvantage relative to colleagues from Purdue, Georgia Tech, etc. who had more practical training. Co-op should be required at MIT, or at least create a course or seminar that teaches standard industry practices for safety & environmental regulations, as well as common systems, architectures, and software. This material evolves every year, but some attempt should be made to expose students. This is also a weakness I see when recruiting MIT students versus other US Engineering schools.

The lack of exposure to finite element analysis methods, to non-destructive examination techniques, and to PRACTICAL design methods is a weakness of the MIT engineering education. The lack of project management, cost estimating, and budget-planning education is also problematic.

It would have been very helpful to have had more training on financial topics and how finance can help rank project priority. When I started my job I learned about NPV, payback, IRR, ROA, etc. This needs to be part of the undergraduate engineering program.

On the negative side, I'm still in debt. And it plagues me, and sometimes I resent it.

As I've become more skilled - asking others how to do things - if they've solved the problem before then they probably have a very good solution. One thing MIT was very bad at was teaching me to ask for help if I'm hosed. At MIT you get no help - so why ask. But when you get older and want to stay sane its important to look out way into the future of a project and determine when things are going to become hectic and ask for help/change the timeline/change the system requirements.

Some aspects in which I think my MIT education could have been much stronger are: written / oral communications, teamwork, and the importance of playing the role of an advocate & agenda setter for things for which I care.

MIT teaches you to be "right" - but in an objective and sometimes confrontational way as I learned in grad school. Unfortunately the world is very subjective...and it can take years to learn about the politics of a work environment. On the subtle side, you can be "right" in a room full of people, but due to the interpersonal presentation it can backfire...just my $0.02.

What could have been better was a more "business" look at engineering. I had to go get an MBA to understand the complete business, but engineers would be better off if they were forced to have a mini-MBA while getting the technical knowledge

Statistics should be required Drawing/CAD/Solidworks/ProE programs should be required Programming should be required Foreign language should be required

Appendix 7: "Other" Professions

Actuary
Adventure Travel Business Owner
Affordable housing developer
Analyst
Banker
Banker
Biological researcher
Business Analyst/Product Manager
Business Development
Business Strategy
Computer Programmer
Computer systems analysis, support, & operations
Corporate Strategy and Business Development
Customer Service Manager
Designer
Director, Business Development (software company)
Engineering Consultant / Contract Engineer
Entrepreneur & CEO of a software company
Finance
Finance
Financial Analyst
Financial Consultant
Financial risk manager, commodities
Former attorney, now in business at a startup
Government administration
Information Security Education
Information Technology (it would not be fair to call it engineering although some would)
Information Technology Analyst
Investment manager
IT Manager
Manufacturing Supply Chain Manager
Marketing
New product development marketing
OEM sales/Business Development
Orthodontist
Own a financial services business
Physics teacher
Private Equity Manager
Product Design
Product Development

Product Marketing
Program Manager
Risk Officer / Insurance Company
Sales & Marketing
Sales and Marketing
Sales Engineer
Scientist
Software Engineer
Sr. Business Planner (financial analyst)
Strategic Initiatives / Business Development
Teacher of Middle/High School Mathematics
Technical Analyst for financial firm
Technology Development Specialist
Trader
Venture Capitalist
Wall Street stock analyst
Web developer / computer programmer

Appendix 8: Gender Analysis

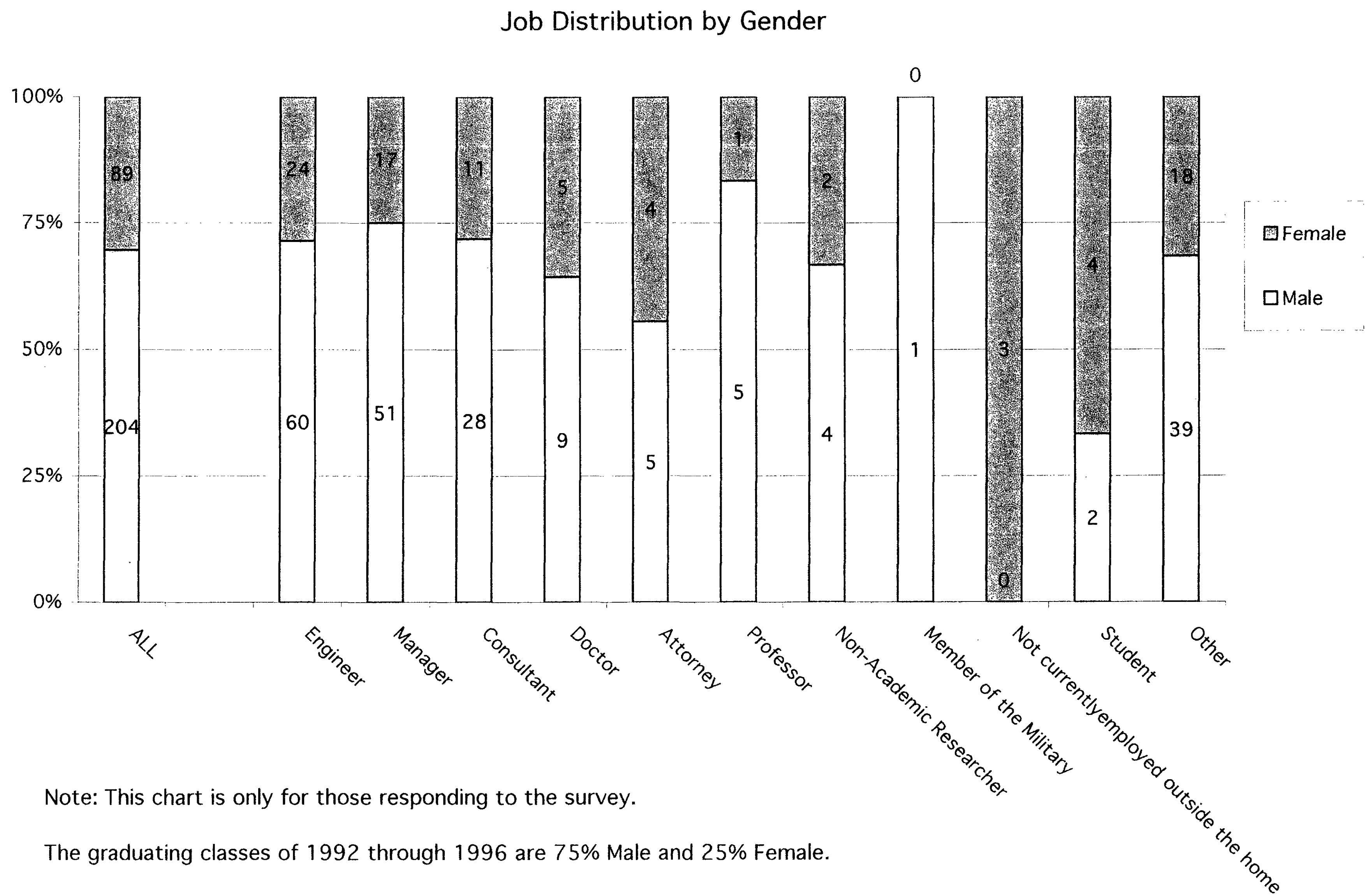
On the next few pages are charts that serve to supplement the gender similarities discussed in the body of the thesis. Below are descriptions of the charts included.

1. Job Distribution by Gender – shows the distribution of males and females in each of the job categories.

2. Breakdown of Professions by Gender – shows the professions chosen by males next to those chosen by females.

3. Mean Proficiency – shows the average proficiency response of males and females to the knowledge and skill areas.

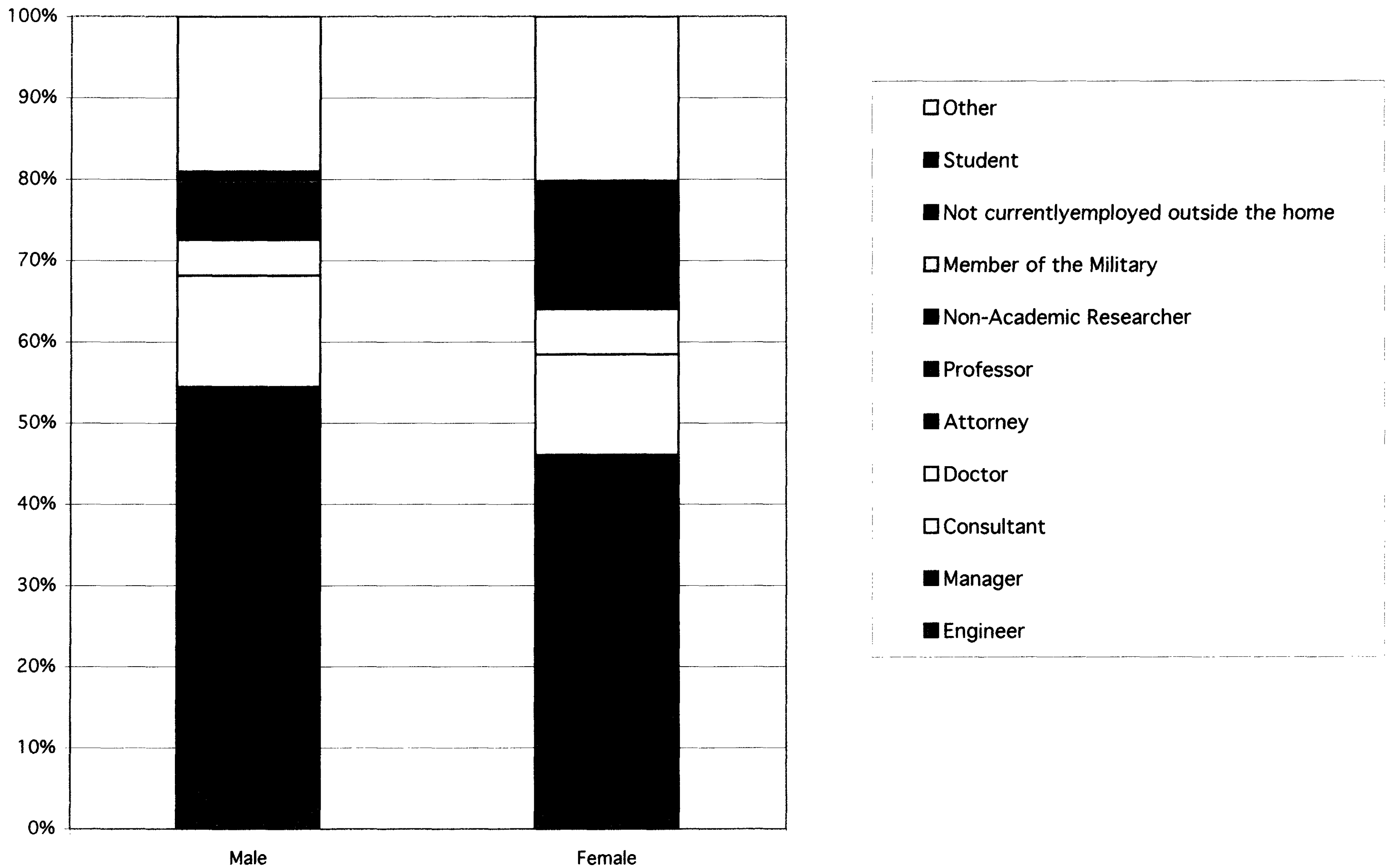
4. Mean Frequency – shows the average frequency response of males and females to the knowledge and skill areas.

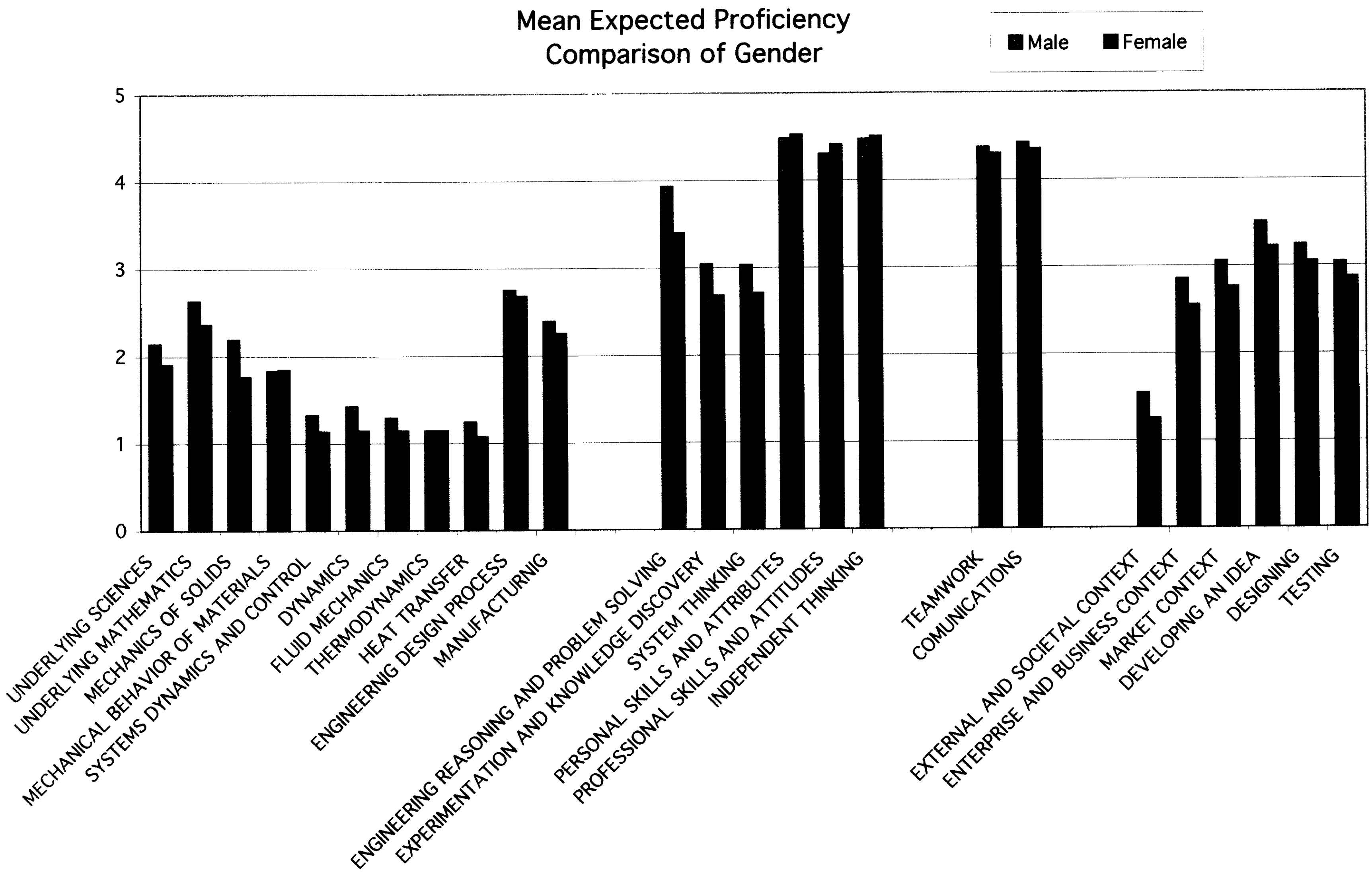


Note: This chart is only for those responding to the survey.

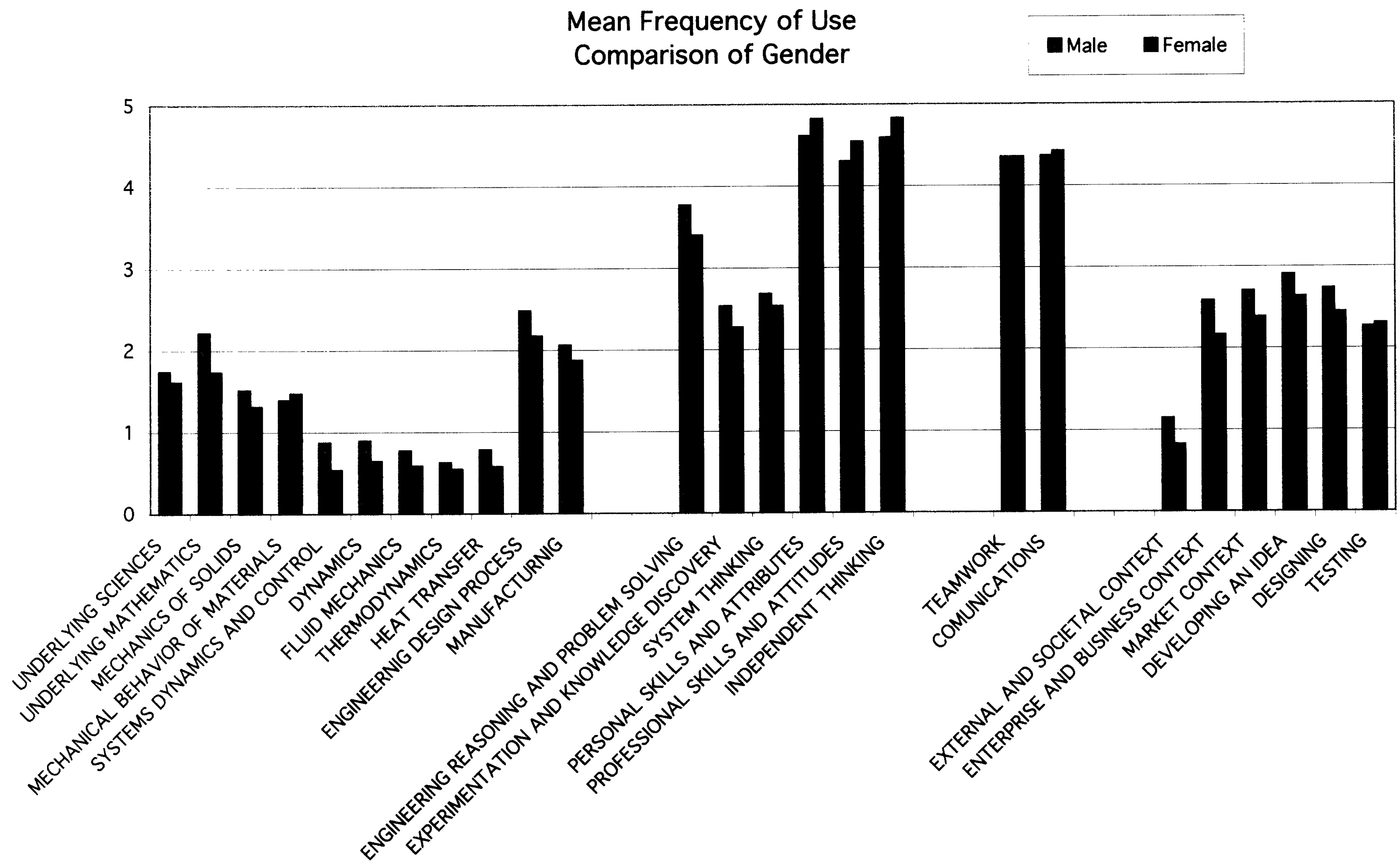
The graduating classes of 1992 through 1996 are 75% Male and 25% Female.

Breakdown of Professions by Gender





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



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

Appendix 9: Procedures for Data Analysis

This appendix discusses in more detail the data manipulation and analysis presented in chapters 3 and 4.

The MIT Survey Service provided the link to a website from which I could download the raw survey data. This data was in the form of comma-separated variables. After the publication of this thesis, the raw data will be transferred onto CD's for easier access.

The data was in five separate files corresponding to the five pages of the survey. I used Excel to open the .csv files. Each file was laid out as shown below, with many more rows for respondents and many more columns for the other knowledge and skill areas.

id	timestamp	Q1PROF.01	Q1FREQ.01	Q1SOUR.01	Q1PROF.02
43003	3/29/04 14:09	2	2	1	3
43007	4/7/04 17:08	1	1	1	1
43011	4/8/04 15:15	4	4	1	5
43016	4/7/04 22:36	4	2	1	3

The ID number is a random number that was assigned to each person who received the survey. I used ID numbers instead of names to protect the anonymity of the respondents. The timestamp indicates the time at which each respondent took the survey. Q1PROF.01 refers to the topic: the Q1 indicates that this is in the first section, technical knowledge and reasoning; PROF refers to which scale is being used (proficiency, frequency or source); .01 indicates that this is the first question in the section, in this case, underlying sciences.

Instead of having one file for each page of the survey, I wanted to have one larger file with all the pages included. To do this, I "copied" each of the files and then "pasted" into one larger file. By hand I confirmed that the ID numbers for each row lined up correctly, adding cells where needed. This was a tedious procedure and could probably be done a different way (possibly using another program to merge the files based on ID number).

The next step in manipulating the data was to sort it into three separate files, one for proficiency, one for frequency and one for source. I did this by "copying" all the proficiency columns and "pasting" into a separate file. I repeated this for frequency and source. These three files were now ready to be transferred to SPSS (Statistical Package for the Social Sciences) for analysis.

A sample of the data file for proficiency is shown on the next page.

ID#	UNDERLYING SCIENCES	UNDERLYING MATHEMATICS	MECHANICS OF SOLIDS
43199	4	4	4
43122	5	6	6
43367	4	4	2
43623	4	4	3
43645	5	5	6

From this point forward I will be discussing only my analysis of proficiency.

Upon opening SPSS, there are two views, the "data view" and the "variable view". The "data view" looks almost identical to Excel. The "variable view" is used to define the variables that will be in each column. Before data can be entered in the "data view", the variables must be defined in the "variable view". For each variable it is necessary to specify the following: name, type, width, decimal, label, value, missing, columns, align, and measure. For most cases I was able to use the defaults. For each topic I specified a name (i.e. science), a type (i.e. numeric), a label (i.e. Underlying Sciences), and values (i.e. 0 = no experience). I left the others as the default.

Once I had defined the variables, I was able to return to the "data view". I "copied" the data from Excel and "pasted" it into SPSS. Now the data was ready for analysis.

Notice in the file at the top of this page that there are some 6's as responses. The scales used in the survey ranked proficiency and frequency from 0-5, but the data was coded using numbers 1-6. To make the data match the scale, I had to subtract 1 from every value in the table. This was done by going to the "Transform" menu and selecting "recode" and then selecting "into same variables". In the box that pops up, I entered "6=5", "5=4", etc. The data was then in workable form.

The first way I looked at the data was in terms of the mean expected proficiency. To do this, I went to the "Analyze" menu, selected "descriptive statistics" and then selected "descriptives". This produced the output seen on the next page.

Descriptive Statistics
Expected Proficiency

	N	Minimum	Maximum	Mean	Std. Deviation
Underlying Science	305	0	5	2.07	1.438
Underlying Mathematics	305	0	5	2.55	1.357
Mechanics of Solids	304	0	5	2.06	1.460
Mechanical Behavior of Materials	305	0	5	1.83	1.748
Systems Dynamics and Control	302	0	5	1.26	1.394
Dynamics	303	0	5	1.34	1.423
Fluid Mechanics	302	0	5	1.25	1.366
Thermodynamics	302	0	5	1.14	1.256
Heat Transfer	301	0	5	1.19	1.312
Engineering Design	302	0	5	2.73	1.999
Manufacturing	301	0	5	2.35	1.875
Engineering Reasoning and Problem Solving	297	0	5	3.77	1.527
Experimentation and Knowledge Discovery	297	0	5	2.94	1.668
System Thinking	296	0	5	2.94	1.852
Personal Skills and Attributes	297	1	5	4.49	.736
Professional Skills and Attitudes	297	1	5	4.33	.783
Independent Thinking	297	1	5	4.48	.740
Teamwork	291	0	5	4.35	.856
Communication	292	0	5	4.40	.709
External and Societal Context	290	0	5	1.45	1.414
Enterprise and Business Context	291	0	5	2.76	1.642
Market Context	291	0	5	2.97	1.683
Developing an Idea	291	0	5	3.42	1.649
Designing	290	0	5	3.18	1.744
Testing	289	0	5	2.99	1.793
Valid N (listwise)	268				

I found it easiest to plot data in Excel, so I needed to export my data. I did this by going to the "File" menu and selecting "export". Files can be exported in the following forms: webpage (.html), text (.txt), Excel (.xls), and Word (.doc). I chose Excel.

After opening the file in Excel, I was able to plot the data as a bar graph.

To understand better the meaning of the averages, I looked at the numbers that people reported for each area. Under the "Analyze" menu, I selected "descriptive statistics" and then selected "frequencies". I ran the function for each of the topics. A sample of the output is shown below.

Underlying Science

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	58	18.8	19.0	19.0
	1	63	20.5	20.7	39.7
	2	40	13.0	13.1	52.8
	3	97	31.5	31.8	84.6
	4	37	12.0	12.1	96.7
	5	10	3.2	3.3	100.0
	Total	305	99.0	100.0	
Missing	System	3	1.0		
Total		308	100.0		

Frequency indicates the number of respondents. Percent is the percent of the total, in this case 308. Valid percent is the percent of the people responding to that particular question, in this case 305.

Again I exported the output data and plotted the bar graph in Excel.

Another important consideration when looking at the data is what profession the respondents are in. The choices were: engineer, technical manager, consultant, doctor, attorney, professor, non-academic researcher, member of the military, not employed outside the home, and other. These were coded in the data file using numbers 1 through 10.

In the case of "other" I went through individually and looked at the job description the respondent provided. In some cases, I recoded the job to a different category. In doing this, I created a new category for students and moved many product managers and other types of managers from the category "other" to "manager". This was done to remain consistent with Catherine Kelly's classifications. Both the original and modified classifications are present in the data files.

To determine the number in each profession, I went to the "Analyze" menu, and selected "descriptive statistics" and then selected "frequencies". The output from SPSS can be seen in the chart on the next page.

Job

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Engineer	84	27.3	28.7	28.7
	Manager	68	22.1	23.2	51.9
	Consultant	39	12.7	13.3	65.2
	Doctor	14	4.5	4.8	70.0
	Attorney	9	2.9	3.1	73.0
	Professor	6	1.9	2.0	75.1
	Non-Academic Researcher	6	1.9	2.0	77.1
	Member of the Military	1	.3	.3	77.5
	Not employed outside the home	3	1.0	1.0	78.5
	Other	57	18.5	19.5	98.0
	Student	6	1.9	2.0	100.0
	Total	293	95.1	100.0	
Missing	System	15	4.9		
Total		308	100.0		

I also used SPSS to distribute the people by graduating class and gender in addition to profession. I input the graduation year data and gender by hand, matching up names, using a data file from the Alumni Association. Once the data was input to SPSS, I went to the "Analyze" menu, selected "descriptive statistics" and then selected "crosstabs" to find the distributions. The output from SPSS can be seen below.

		Gender		Total
		Female	Male	
Job	Engineer	24	60	84
	Manager	17	51	68
	Consultant	11	28	39
	Doctor	5	9	14
	Attorney	4	5	9
	Professor	1	5	6
	Non-Academic Researcher	2	4	6
	Member of the Military	0	1	1
	Not employed outside the home	3	0	3
	Other	18	39	57
	Student	4	2	6
Total		89	204	293

		Year					Total
		1992	1993	1994	1995	1996	
Job	Engineer	17	11	17	11	25	81
	Manager	14	12	11	17	12	66
	Consultant	9	3	4	13	9	38
	Doctor	5	2	2	0	5	14
	Attorney	3	2	1	0	2	8
	Professor	2	1	1	0	1	5
	Non-Academic Researcher	0	1	0	4	0	5
	Member of the Military	0	0	0	0	1	1
	Not employed outside the home	0	0	0	2	1	3
	Other	7	16	13	13	5	54
	Student	1	0	1	4	0	6
Total		58	48	50	64	61	281

Notice in the preceding tables that the totals are not all 308. Although there were 308 survey respondents, not everyone had complete occupation, gender and year data.

Again I exported the output data to Excel and plotted the bar graphs.

Since the respondents' professions were known, I was able to run my analysis of average proficiency again using only selected groups of people. I went to the "Data" menu, the selected "select cases" and then "if condition satisfied" to select the engineers (job = 1). I then ran the "descriptives" function as described previously to obtain the mean expected proficiency for each area. I repeated this for the managers, consultants, and others (where 'others' now refers not only to those who reported other, but to all those who do not fit into the categories of engineer, manager or consultant). I exported to Excel and plotted.

I repeated the same procedure for graduating year and gender.

The entire process described above was repeated for frequency and source.

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Executive Summary

Understanding the Careers of the Alumni of the MIT Mechanical Engineering Department

by

Kristen E. Wolfe

Undergraduate Thesis, June 2004

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The purpose of this research is to understand more clearly what knowledge and skills graduates of the MIT Mechanical Engineering Department make use of in their professions. The vision and mission of this research are as follows:

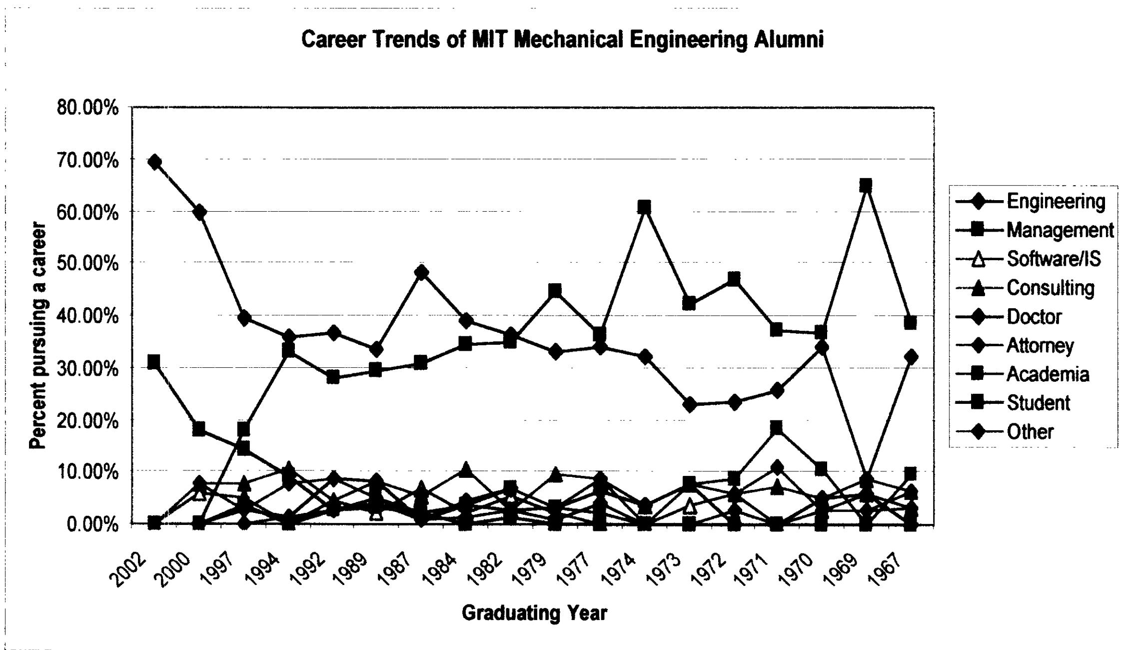
VISION: The mechanical engineering curriculum will prepare our graduates to be leaders in their chosen professions. By leaders we mean the people in a given profession who are highly regarded by their peers and other professional colleagues.

MISSION: We will learn about the professional activities of our graduates in order to discern what specifically they do in their jobs, and then use that to tailor our curriculum to reflect the needs of our alumni.

The hope is that by better understanding what MIT mechanical engineering graduates need and use in their professions, the department can then know how to better prepare the undergraduate students for their futures.

<u>Background:</u>

My work follows on the research of Catherine Kelly in her undergraduate thesis entitled "Some Trends in the Career Paths Followed by Alumni of the MIT Mechanical Engineering Department" [1]. Her research focused on determining what careers graduates chose after leaving MIT. She obtained data on the current occupations of the graduating classes of 1967 through 2002. Her results can be seen on the graph below:



As can be seen above, Catherine Kelly found that approximately 70% of MIT mechanical engineering graduates enter into technical fields while the others pursue a wide variety of career paths. Within the technical career paths, the graduates focus over time on either the management or the engineering realm.

Research Method

The idea for this research was to have a better understanding of the knowledge and skills that mechanical engineering graduates make use of in their careers. The graduates selected to be studied are from the classes of 1992 through 1996. These graduates were chosen because this research seeks to determine how best to prepare students to become leaders in their chosen fields. As Prof. Seering explains, "By the age of 30, our alumni will have achieved a level of professional accomplishment sufficient to enable them to begin to accept significant leadership responsibility" [2].

To gather information about the knowledge and skills graduates need, I used a survey. The survey was based off of work previously conducted by Prof. Crawley in the Aeronautics and Astronautics Department at MIT [3]. He created an engineering syllabus to cover the areas of knowledge and skills that all engineers should know upon graduation. I modified this syllabus slightly to align the topics with those taught in the mechanical engineering department. The version used is shown below.

1 Technical Knowledge and Reasoning
    1.1 Underlying Sciences
    1.2 Underlying Mathematics
    1.3 Mechanics of Solids
    1.4 Mechanical Behavior of Materials
    1.5 System Dynamics and Control
    1.6 Dynamics
    1.7 Fluid Mechanics
    1.8 Thermodynamics
    1.9 Heat Transfer
    1.10 Engineering Design Process
    1.11 Manufacturing

2 Personal and Professional Skills and Attributes
    2.1 Engineering Reasoning and Problem Solving
    2.2 Experimentation and Knowledge Discovery
    2.3 System Thinking
    2.4 Personal Skills and Attributes
    2.5 Professional Skills and Attitudes
    2.6 Independent Thinking

3 Interpersonal Skills
    3.1 Teamwork
    3.2 Communications

4 Engineering Skills
    4.1 External and Societal Context
    4.2 Enterprise and Business Context
    4.3 Market Context
    4.4 Developing an Idea
    4.5 Designing
    4.6 Testing

The survey asked the graduates to rate the topics above on the following criteria:

1. <u>Expected Proficiency</u>
   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?
    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. <u>Frequency of Use</u>
   In your present position, how frequently do you employ the knowledge and skills from each of these areas?
    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

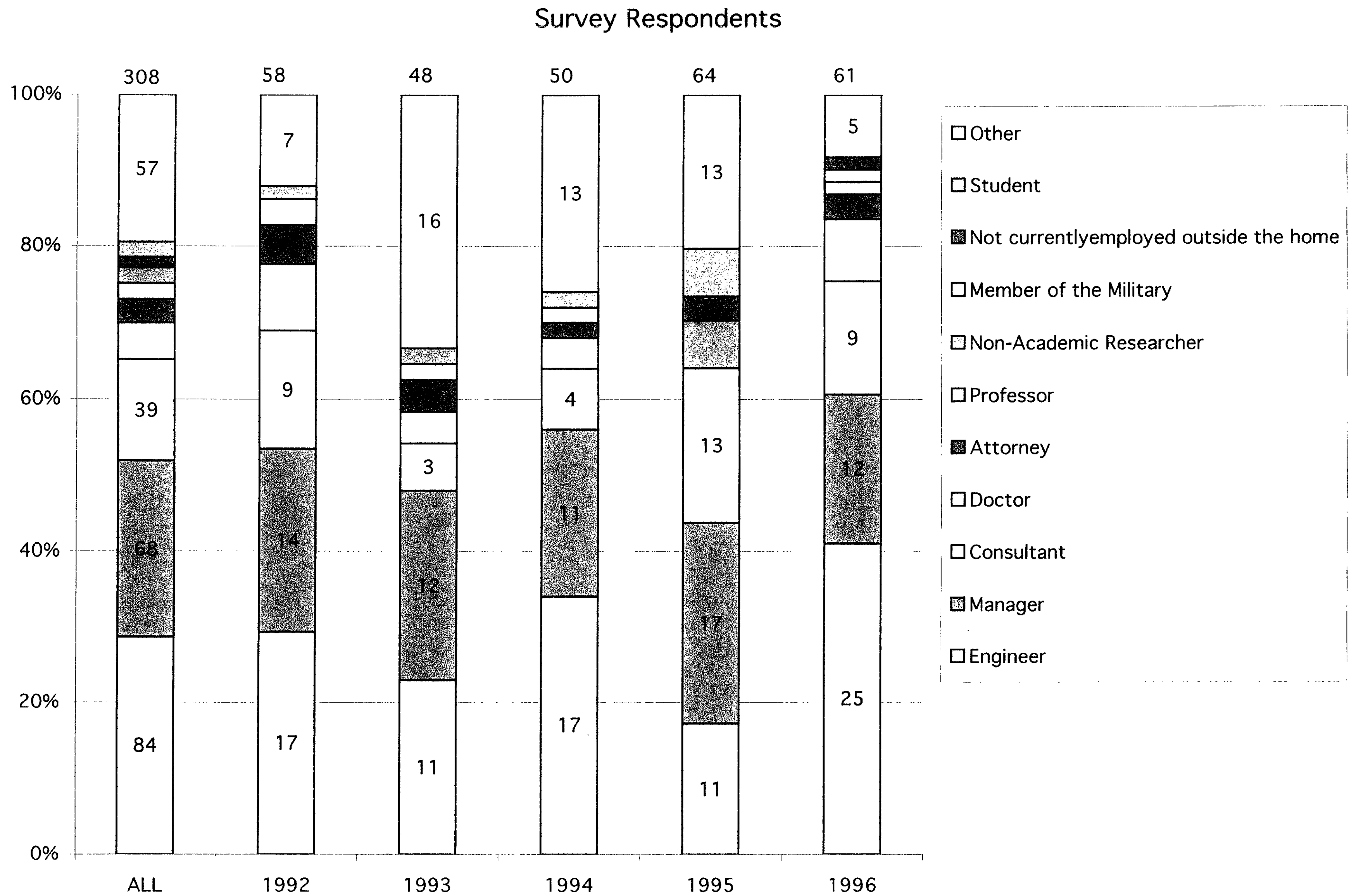
3. <u>Source of Your Knowledge</u>
   Where did you gain the most understanding about each topic?
    - U – Undergraduate Program at MIT
    - G – Graduate School
    - J – Job
    - E – Somewhere Else
    - N – Did Not Learn

The survey was run online. 676 graduates from the classes of 1992 through 1996 were emailed asking for their participation. 308 graduates completed the survey, a 46% response rate.

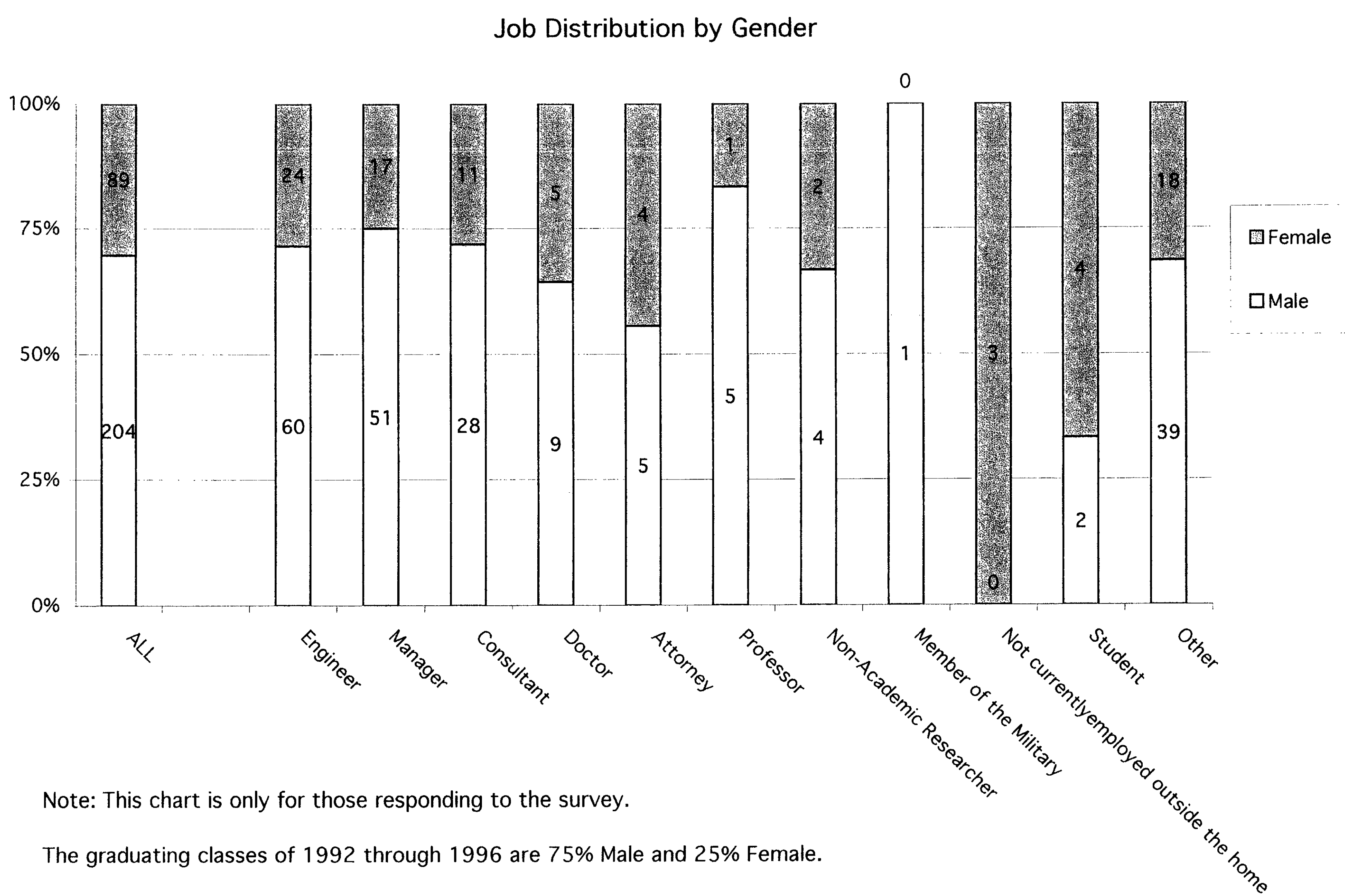
Results

On the next few pages the results of the survey are displayed visually. Below are descriptions of the charts included.

1. Survey Respondents - shows the distribution by profession and year of those who completed the survey.
2. Job Distribution by Gender – shows the breakdown of professions by gender.
3. Mean Proficiency and Frequency of Use – shows the average responses for each of the knowledge and skill areas.
4. Source – shows the distribution of responses for primary source of knowledge.



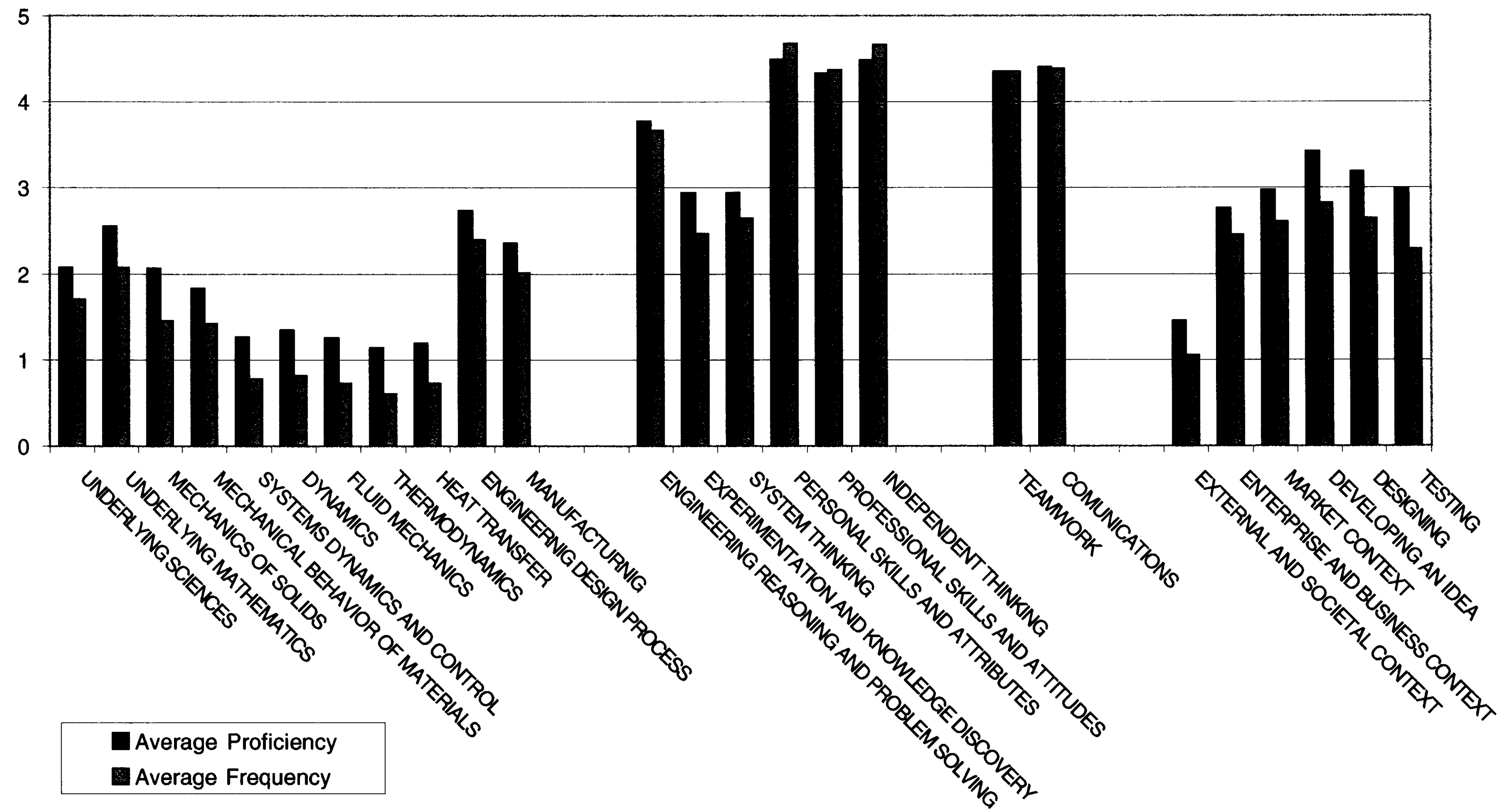
Survey Respondents
308
58
48
50
64
61
100%
80%
60%
40%
20%
0%
57
39
68
84
7
9
14
17
16
3
12
11
13
4
11
17
13
13
17
11
5
9
12
25
ALL
1992
1993
1994
1995
1996
Other
Student
Not currentlyemployed outside the home
Member of the Military
Non-Academic Researcher
Professor
Attorney
Doctor
Consultant
Manager
Engineer



Note: This chart is only for those responding to the survey.

The graduating classes of 1992 through 1996 are 75% Male and 25% Female.

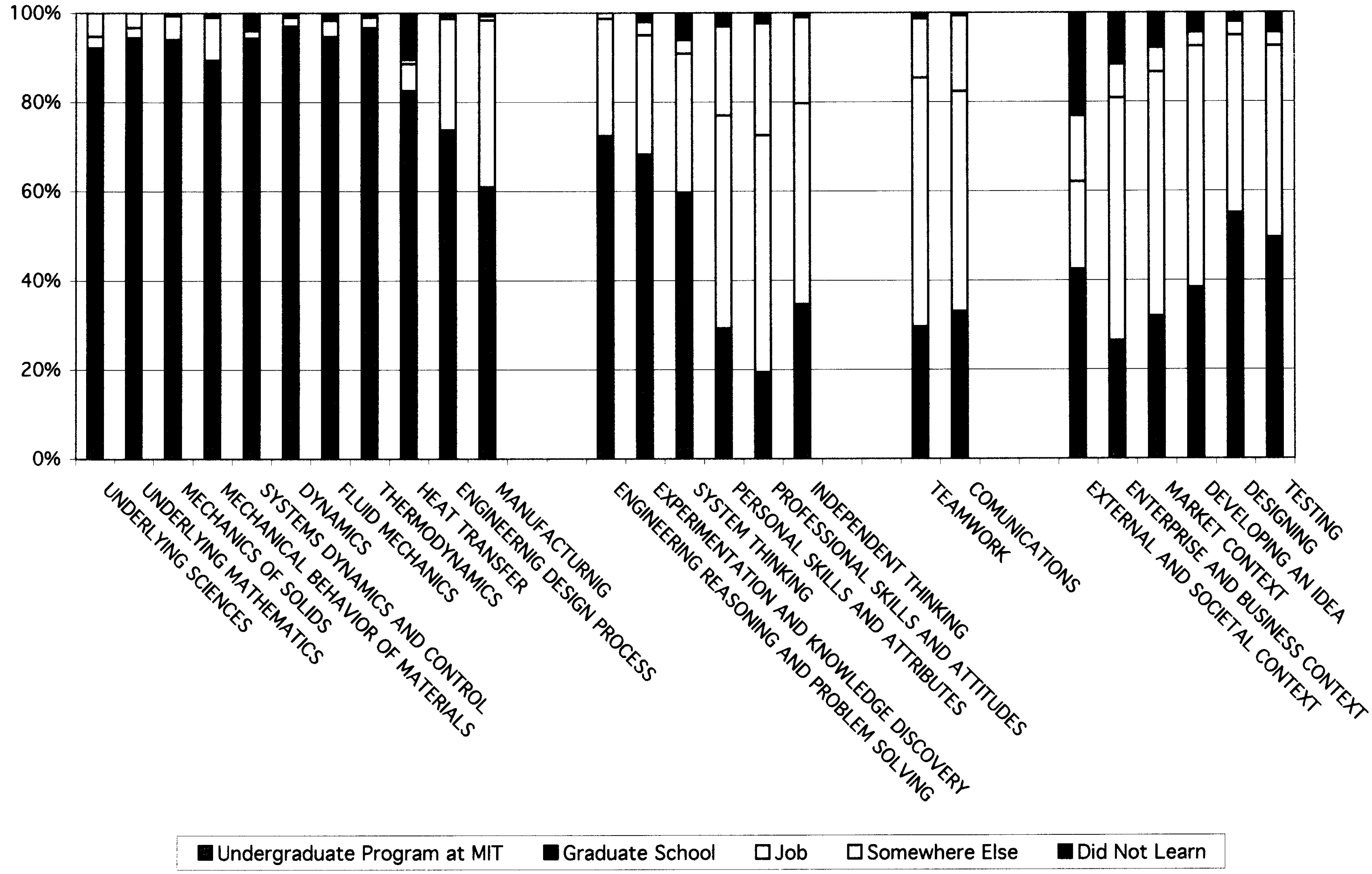
Mean Expected Proficiency and Frequency of Use



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


100%
80%
60%
40%
20%
0%
UNDERLYING SCIENCES
UNDERLYING MATHEMATICS
MECHANICS OF SOLIDS
MECHANICAL BEHAVIOR OF MATERIALS
SYSTEMS DYNAMICS AND CONTROL
DYNAMICS
FLUID MECHANICS
THERMODYNAMICS
HEAT TRANSFER
ENGINEERNIG DESIGN PROCESS
MANUFACTURNIG
ENGINEERING REASONING AND PROBLEM SOLVING
EXPERIMENTATION AND KNOWLEDGE DISCOVERY
SYSTEM THINKING
PERSONAL SKILLS AND ATTRIBUTES
PROFESSIONAL SKILLS AND ATTITUDES
INDEPENDENT THINKING
TEAMWORK
COMUNICATIONS
EXTERNAL AND SOCIETAL CONTEXT
ENTERPRISE AND BUSINESS CONTEXT
MARKET CONTEXT
DEVELOPING AN IDEA
DESIGNING
TESTING
Undergraduate Program at MIT
Graduate School
Job
Somewhere Else
Did Not Learn

For further information or questions about this research please contact:
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To request a copy of the complete thesis, please contact the MIT Libraries.

References

[1] 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.

[2] Seering, W., 2004, Presentation to the Engineering Committee on Undergraduate Education, Massachusetts Institute of Technology, Cambridge, MA.

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