Re-engineering Engineering: How Course 2-A is Paving the Way for Interdisciplinary Engineering Education at MIT

by

Shanette A. Go

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Submitted to the Department of Mechanical Engineering
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At the Massachusetts Institute of Technology

ABSTRACT

In 2004, The National Academy of Engineers (NAE) released a report calling for changes to be made to the current engineering education system in response to the growing need for engineering graduates who would be able to understand engineering problems in a larger context. The present study hopes to gain a better understanding of the growth of flexible engineering education by determining differences in student characteristics and their effect on a student's choice of academic program, identifying the perceptions of the MIT community of flexible and traditional engineering programs and how these perceptions changed over time, and establishing whether or not a correlation exists between students' perceived self-efficacy in engineering and professional abilities and his or her career plans. An online survey was developed and administered to the Course 2 and Course 2-A student body. Significant differences in motivation, opinion of Course 2 and Course 2-A, as well as perceived self-efficacy were found between Course 2 and Course 2-A students.

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1. Introduction

The introduction of Course 2-A as a major in 1934 by the MIT Mechanical Engineering Department clearly indicates the administration's early recognition of the need for flexible engineering degrees that challenge the boundaries set by engineering disciplinary majors and careers. Course 2-A was conceived in response to students "whose academic and career goals demand greater breadth and flexibility than can be realized under the mechanical engineering program, Course 2." [5] Although the Course 2-A degree requirements have since changed, the major remains true to its original purpose: to equip its students with a strong background in the fundamentals of mechanical engineering, while offering students the ability to customize their curriculum to meet their interdisciplinary engineering interests. Students can focus in a number of common concentrations (such as biomedical engineering/pre-medicine, energy, product design, engineering management, robotics, sustainable development, and architecture and building technology) or design their own concentration.

This thesis will explore the Course 2-A major offered by the Mechanical Engineering department at MIT by posing the following questions:

- Do differences in motivation exist that determine a student's choice of major?
- How do students perceive Course 2 and Course 2-A? Do Course 2 and Course 2-A students perceive each course differently? Do these perceptions change (positively or negatively) over time?
- What is the relationship between a student's choice of major and his or her self-efficacy? Is there a correlation between a student's perceived self-efficacy in engineering and professional abilities and his or her long-term career goals?

2. Background

The word "engineer" derives its meaning from the Latin words *ingenia*, to design or devise, and *ingenium*, cleverness. Indeed, from the design of bridges to the fabrication of the first computer, the field of engineering has played an integral role in the development of valuable new technologies that serve to improve the quality of life in society.

In the last half-century, science and technology have grown exponentially, dramatically changing the needs of society. In response to these changes, the study of engineering has expanded beyond its traditional disciplinary branches to include subspecialties such as biomechanics and microelectronics. Yet, the breadth of knowledge required to solve many modern-day engineering problems is too broad to be covered by a single engineering subspecialty. As a result, the need for a "systems perspective" – one that integrates the diverse knowledge and skills from multiple disciplines, both engineering and non-engineering – has become increasingly prevalent.[9]

2.1 The need for interdisciplinary engineering degrees

The National Academy of Engineering (NAE) recognized the evolution of the field of engineering, and, in an initiative to understand these changes and prepare for the future, released a two-part report in 2004 and 2005 that answered the question "What will or should engineering be like in 2020?"[6, 7] The NAE envisioned engineering graduates who would not only be leaders in their fields, but also be strong communicators, business managers, collaborative team workers, and life-long learners who would be able to understand engineering problems in the social, economical, political, and global contexts.[7]

With these characteristics in mind, the NAE suggested several changes that could be made to the current engineering curriculum to better prepare graduates for the present and future needs of society. In particular, the NAE recommended students not only receive a strong education in math and science concepts fundamental to engineering, but also gain familiarity with topics in the humanities and social sciences.[1] This movement towards the integration of engineering with liberal arts would provide "the knowledge, skills, and breadth of thinking necessary to perform in leadership roles in government, industry, and, more broadly, all aspects of society."[7]

2.2 Flexible engineering degrees: a nationwide trend

In 2000, the Accreditation Board of Engineering Education (ABET) introduced Criterion 3 (a-k) "Program Outcomes" as one of its required standards for accreditation of undergraduate engineering programs. These eleven standards outline specific skills and knowledge that students should develop and be able to apply by the time they graduate, and encourage undergraduate institutions to ensure that students graduating from their engineering programs "can not only apply technical engineering knowledge and carry out experiments required in engineering work, but also are able to communicate in writing and orally, work in multidisciplinary teams, carry out the engineering design process, and understand the impact of engineering solutions in a global or society context." [8]

Several institutions around the nation have taken steps to integrate both the new ABET requirements and NAE recommendations into their curricula. For instance, Columbia University now offers a 5-year program that combines three years of liberal arts studies with two years of engineering studies; graduates from this program earn both a Bachelor of Arts (B.A.) in liberal arts and a Bachelor of Science (B.S.) in engineering.[4] Similarly, many institutions now offer a B.A. in Engineering programs. Students at Lafayette College, for example, spend their first year studying the same engineering subjects as B.S. students. In the following years, they can then choose from electives in economics, management, policy, or liberal arts that prepare them for future careers in areas such as policy, technology law, engineering management, or engineering.[7,8]

2.3 The Course 2-A degree program at MIT

The goal of the Course 2-A degree program at MIT is to combine two non-traditionally overlapping disciplines and allowing students to focus their studies and energy in a specific area of interest while simultaneously obtaining a strong background in mechanical engineering principles. At the time of its inception, Course 2-A was a loosely flexible degree with very informal requirements. In an effort to ensure that students were equipped with fundamental engineering knowledge and skills, the requirements were expanded to include core classes in basic mechanical engineering theories, experimentation and design – such as 2.001 (Mechanics and Materials I), 2.671 (Measurement and Instrumentation), and 2.009 (The Product Engineering Process). Although students are required to take several of these core classes, they maintain their ability to select the upper level mechanical engineering courses that fulfill their second-level and concentration requirements.

In 2001, the program was accredited as an engineering degree by ABET and described as an "exemplary program" that "represented the future of engineering."[4] Since its accreditation, Course 2-A has become increasingly popular among the student body, with its total enrollment expanding from 31 students in 2001 to over 120 students in 2008 (Figure 1)[3] – a 400% increase in less than a decade!

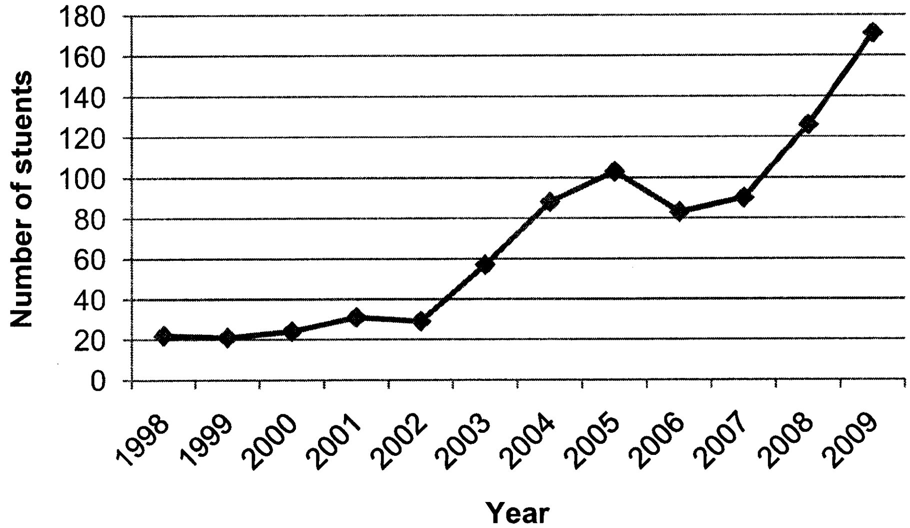


Figure 1. Course 2-A total enrollment data: 1998 – 2009 academic years. This data only includes sophomores, juniors, and seniors who were officially enrolled in the Course 2-A program at the beginning of the academic year.

With this rapid growth in enrollment in the Course 2-A program, it would be valuable to discern the factors that encourage students to choose this flexible engineering program rather than a traditional engineering major. The purpose of the present study is to identify some of these factors, including student characteristics and students' perceptions of the differences between the two types of engineering majors.

2.4 Intrinsic and extrinsic sources of motivation

Students entering college must make several important decisions regarding their future career path. First and foremost is their choice of academic major; although a student's major is not always directly linked to his or her career choices, it is often an accurate predictor of his or her career path. In making this decision, whether a student is primarily motivated by intrinsic or extrinsic factors may be revealed.

Intrinsic motivation refers to performing tasks or participating in activities for the personal satisfaction that can be gained; this includes a student's personal curiosity about a specific topic such as energy or management, or a career goal that a student wishes to achieve. Students who choose a major for primarily intrinsic reasons may be more invested in their learning and derive a greater sense of satisfaction from those learning activities.

In contrast, extrinsic motivation refers to performing tasks or participating in activities in response to achieve "separable outcomes" – for example, taking a class that will be valuable for a future career, as opposed to taking a class to fulfill personal interest. Students who are extrinsically motivated may also be affected by external pressures such as the approval and opinion of their parents and peers. Students who choose to major for primarily extrinsic reasons may be less invested in their learning and feel less satisfied with their studies.[9]

2.5 Self-efficacy as a determinant of career goals

Perceived self-efficacy is defined as a person's belief in his or her abilities to successfully complete a task or reach a goal. The choices that people make are directly governed by their perception of their self-efficacy – people will gravitate towards activities and situations that they are confident they will succeed in and avoid situations that require skills and abilities that they might lack.[1]

According to Albert Bandura, students who have the opportunity to successfully complete a real-life task report an increase in their perceived self-efficacy. Such "mastery experiences," such as the product design process, may be incorporated into engineering courses to allow students to perform tasks similar to those that they may be required to perform in the real-world. Furthermore, the career decisions made by college-aged students will be directly impacted by their confidence in their abilities: "the higher the level of people's perceived self-efficacy the wider the range of career options they seriously consider, the greater their interest in them, and the better they prepare themselves educationally for the occupational pursuits they choose and the greater is their success."[1]

3. Surveying the Course 2 and 2-A student body

In order to collect student feedback, a 39-question survey was developed and administered through SurveyMonkey, a web-based survey service provider; actual survey questions may be found in Appendix I. A total of 430 students from the graduating classes of 2010, 2011, and 2012 enrolled in the Mechanical Engineering Course 2 and Course 2-A programs were invited to participate in the survey through email and provided a link that would allow them to access and respond to the survey. Of the 430 students invited to participate, 150 students successfully completed the survey, 124 of whom disclosed their chosen major; the participation numbers according to graduation year and major are shown in Table 1.

Table 1. Participation numbers of Course 2 and Course 2-A students according to graduation year. A total of 150 students completed the survey; however, only 124 disclosed their major.

	2010	2011	2012	Total
2	28	29	22	79
2-A	18	15	12	45
Total	46	44	34	124

Students were asked several course-specific questions based on the major they designated in the survey to collect data on potential areas of improvement within each department, such as faculty advising and communication between each department and its students.

To gain a better understanding of how the MIT community perceives Course 2-A, students were asked to rate the opinion of various groups within the MIT community on Course 2 compared to Course 2-A and vice versa, on a 5 point scale (1-5), where 1 corresponds to a response of "negatively," and 5 corresponds to a response of "positively". Students were also asked to elaborate on how their opinion of both courses changed during their time at MIT in order to identify differences in student mindset. This feedback was solicited through open-ended questions, which provided students with the opportunity elaborate further on previous responses or to provide feedback that would otherwise not be captured by multiple-choice or rating questions.

The survey included self-efficacy questions that measured the ability of students to complete tasks that fall under the following themes of engineering design: use of technical engineering concepts and engineering math, design process and innovation, understanding the social implications of technology, problem solving, written and oral communication, and teamwork. These skills were further categorized into two subthemes: disciplinary engineering skills and interdisciplinary engineering skills. Disciplinary engineering skills are the skills that students are expected to develop through their coursework in a single engineering discipline; interdisciplinary skills are the skills that students are expected to develop through their coursework in multiple engineering disciplines. Example survey questions are shown in Table 2. Students were asked to rate their confidence on a Bandura-type confidence scale in their ability to complete 22 tasks on an 11 point scale (1-11), where 1 corresponds to "not at all confident" and 11 corresponds to "extremely confident."

Table 2. Sample subtheme survey questions.

Subtheme	Sample question
Disciplinary engineering	Recognize underlying technical principles in a complex problem.
Interdisciplinary engineering	Carefully balance technical, economic, and cultural factors in making project choices.

Finally, students were asked about their immediate plans for after graduation and their long-term career plans. Students also rated how certain they were about these plans, on a scale from 1-5, where 1 corresponds to a response of "not certain at all" and 5 corresponds to a response of "very certain."

4. Results

Mean scores were computed and analyzed for each question. Students in the graduating class of 2012 were not included in the analysis when comparing Course 2 and Course 2-A responses as a whole. As a result, only the responses of 57 Course 2 and 33 Course 2-A juniors and seniors were considered for these analyses. The decision to exclude the responses of students in the graduating class of 2012 was made in light of the fact that most of these students had only completed one semester of their Mechanical Engineering coursework when the survey was administered. Thus, they had yet to gain enough familiarity with the program or relevant skills to give feedback relevant to this study.

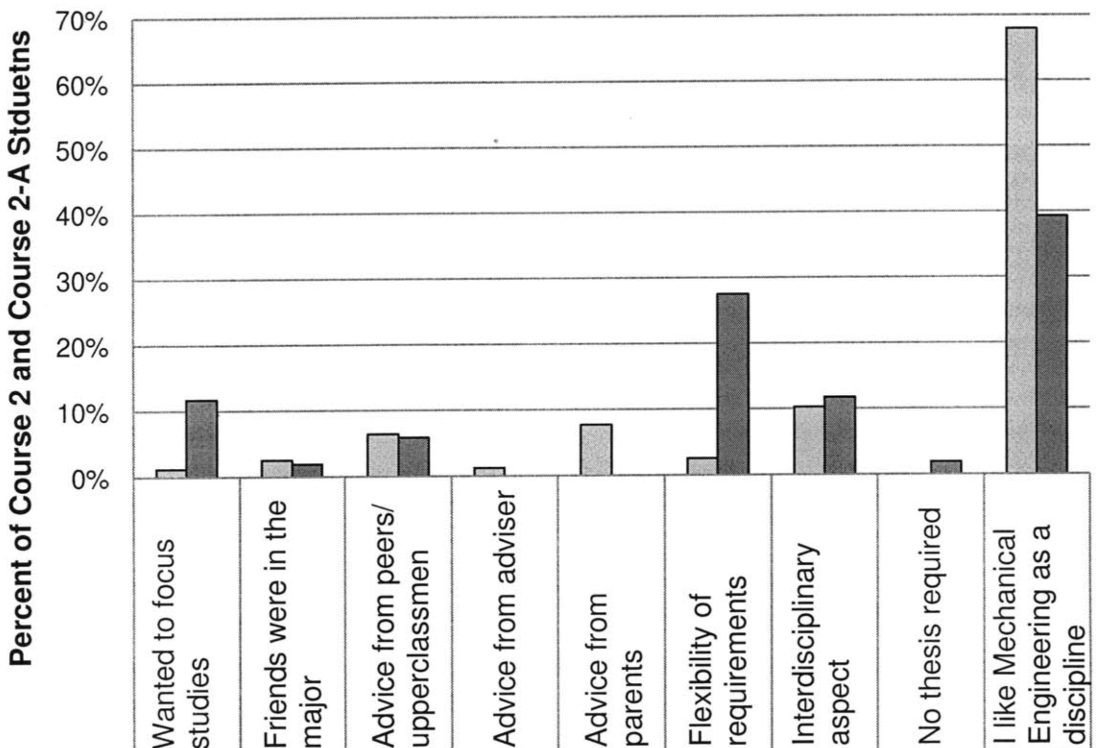
4.1 Choice of major: motivation

Students were told to select the main reason why they chose their major; Figure 1 displays the results for students' motivation for their choice of major.

The majority of Course 2 students (N = 86) chose their major because they liked "Mechanical Engineering as a discipline," while several noted that advice from peers, faculty, or family influenced their decision to major in Course 2. Less than 5% of Course 2 students who responded said that they "wanted to focus studies," and over 25% said that it was because of the "flexibility of the requirements."

In contrast, of the Course 2-A students who responded (N = 54), over 10% said that they "wanted to focus studies," and over 25% said that it was because of the "flexibility of the requirements." These sentiments are also reflected in their comments on combining multiple disciplines into a single degree:

- "This gave me the opportunity to take courses more aligned with my interests, including graduate-level product design courses."
- "I am interested in sustainable design of buildings and alternative energies."
- "I'm interested in entrepreneurship. I would like to pursue a career in international development, and become involved in non-profits."



	Wanted to focus studies	Friends were in the major	Advice from peers/ upperclassmen	Advice from adviser	Advice from parents	Flexibility of requirements	Interdisciplinary aspect	No thesis required	I like Mechanical Engineering as a discipline
Course 2	1%	3%	6%	1%	8%	3%	10%	0%	68%
Course 2-A	12%	2%	6%	0%	0%	27%	12%	2%	39%

Figure 1. Breakdown of motivation for students' choice of major. A total of 54 Course 2-A (yellow) and 86 Course 2 (purple) students from the graduating classes of 2010, 2011, and 2012 provided a response to this question.

4.2 Changing perceptions

4.2.1 The Course 2 perspective

Students in Course 2 (N = 57) were asked to rate the perceptions of their peers, the faculty, their family, and themselves of Course 2 compared to Course 2-A on a 5 point scale, where a score of 1 corresponded to a very negative perception and a score of 5 corresponded to a very positive perception. In addition, students rated how much the opinion of these groups of people (excluding themselves) impacted their decision to major in Course 2. The average ratings of all Course 2 students are shown in Table 3 and Table 4.

Table 3. Perception of Course 2 as compared to Course 2-A of different peer groups. The average ratings of Course 2 students (N = 57) are reported by graduation year (2010, 2011, and 2012). Reponses were rated on a scale from 1-5, where a score of 1 indicates a negative perception, while a score of 5 indicates a positive perception.

	Average Rating		
	2010	2011	2012
Peers	3.82	3.57	3.19
Faculty	3.61	3.50	3.38
Family	3.36	3.43	3.43
Yourself	3.86	3.79	3.67

Table 4. Influence of peer groups on students' decision to major in Course 2. The average ratings of Course 2 students (N = 57) are reported by graduation year (2010, 2011, and 2012). Responses were rated on a scale from 1-5, where a score of 1 indicates no influence, while a score of 5 indicates a heavy influence.

	Average Rating		
	2010	2011	2012
Peers	2.34	1.72	1.67
Faculty	1.76	1.34	1.48
Family	1.52	1.69	1.60

Students were asked how their perception of Course 2-A had changed over time. The majority of Course 2 students who responded perceived Course 2-A in a more negative light; a large percentage of Course 2 students voiced concerns about the lack of a formal degree in Mechanical Engineering and prestige, and generally viewed Course 2-A as an "easy way out" of difficult courses required by Course 2:

- "The fact that the degree says 'as recommended by the Mechanical Engineering Department' is kind of unsettling. It is my understanding that it is not an 'official' degree although it does pretty much count as a degree." (2010)
- "It seems like an "easy" version of Course 2 that allows its students to skip the most difficult classes that Course 2 students must take." (2011)
- "It seems like it is a weaker and less rigorous program than normal Course 2. I would hesitate to do Course 2-A because it seems to lack the same rigor and prestige that Course 2 has." (2012)

However, a small percentage of respondents indicated that their perception of Course 2-A, in particular the students' ability to focus in a specific area related to mechanical engineering, had actually become more positive over time:

- "I have come to respect it more and see it is an option for people who are interested in mechanical engineering but want to focus in a particular field." (2010)

- "It seems like a better option now than when I started the major because you can concentrate in Course 2 disciplines that you are excited about and not take the "bad" classes." (2010)
- "Sounds more reasonable than I first thought. Mechanical engineers need to be very diverse in their knowledge of mechanics, electronics, etc in order to be good at what they do." (2012)

Interestingly, when students were asked about how their perception of Course 2 had changed over time, the majority of the comments indicated a general dissatisfaction with the rigid requirements and disconnect between what is taught in the classroom and what is ultimately useful for their careers.

- "It is a little restricting, not allowing students time/knowledge about classes like D-lab" (2010)
- "It is not as applicable to the real world as I would have wanted. It focuses on material that is too old. Some of the courses are irrelevant to some students." (2010)
- "We learn a lot of things that are important and completely useless in the real world." (2010)
- "Most of the classes teach the stuff which anyone can learn easily when one enters in industry. Also, they spent too much time in teaching approximation. I guess I don't find it that I am learning much." (2011)
- "I learned more about Course 2 from one independent project than all of the classes I've taken." (2010)

4.2.2 The Course 2-A perspective

Students in Course 2-A (N = 33) were asked to rate the perceptions of their peers, the faculty, their family, and themselves of Course 2-A compared to Course 2 on a 5 point scale, where a score of 1 corresponded to a very negative and a score of 5 corresponded to a very positive perception. In addition, students rated how much the opinion of these groups of people (excluding themselves) impacted their decision to major in Course 2-A. The average ratings of all Course 2-A students are shown in Table 5 and Table 6.

Table 5. Perception of Course 2-A as compared to Course 2 of different peer groups. The average ratings of all Course 2-A students (N = 33) are reported by graduation year (2010, 2011, and 2012). A score of 1 indicates a negative perception, while a score of 5 indicates a positive perception.

	Average Rating		
	2010	2011	2012
Peers	2.67	2.73	3.08
Faculty	3.00	3.33	3.17
Family	3.50	3.60	4.00
Yourself	4.00	4.27	4.33

Table 6. Influence of peer groups on students' decision to major in Course 2-A. The average ratings of all Course 2-A students (N = 33) are reported by graduation year (2010, 2011, and 2012). A score of 1 indicates no influence, while a score of 5 indicates a heavy influence.

	Average Rating		
	2010	2011	2012
Peers	1.50	1.67	1.50
Faculty	1.39	1.67	1.33
Family	1.44	2.00	1.58

Course 2-A students indicated that their peers generally viewed Course 2 more positively than they did Course 2-A. However, this perception had almost no impact on the decision of students to major in Course 2-A, regardless of graduation year. It is still important to note that the perception of students' peers of Course 2-A as compared to Course 2 have become more positive over the years (increasing by an average of 0.2 points from year to year).

Students were asked how their perception of Course 2-A had changed over time. In general, students perceived Course 2-A not as a "cop out," but as an intrinsically motivated choice about their education:

- "I feel like the core classes offered in Course 2 give enough background that I am well-informed, and whatever field I choose in the future, I can use the information and skill sets I've learned to learn more." (2011)
- "I like the hybrid degree and don't feel like I've shortchanged my MIT experience – rather I've strengthened it." (2011)
- "As my college career progressed, I realized it was stupid to take classes just because they are requirements if I wasn't interested in the content. So I realized that Course 2-A would relieve some of those required classes and would be a better fit for my interest." (2011)

Students were also asked to share how their opinion of Course 2 changed over time. Many students observed that the requirements were too structured and not applicable to their future goals; students also commented that the scope of major was much more broad than they initially thought:

- "I think over time I was more and more glad I wasn't Course 2 as I saw that many of the courses would not be nearly as useful to my life after MIT (and I wasn't as motivated to study since I didn't have an interest in them)" (2010)
- "Course 2 has way too many requirements, and is way more theoretical and less applicable than 2-A." (2011)
- "I prefer Course 2-A, I feel that people in Course 2 take classes that are required without much thought as to what really interests them, sometimes. But I feel like with 2-A I have flexibility to make my course of study support my interests. This doesn't guarantee higher grades, but at least I have satisfaction with the classes I'm taking." (2011)

4.3 Perceived self-efficacy

A self-efficacy survey was administered to determine students' rating of their abilities developed through an engineering curriculum. Only the responses of juniors and seniors were included in the analysis.

Course 2-A students reported a higher average self-efficacy rating than Course 2 students on 19 out of the 22 questions asked. Furthermore, Course 2-A students scored at least one point higher than Course 2 students did on 9 abilities, 5 of which were classified as "interdisciplinary engineering skills." Average Course 2-A scores were plotted against corresponding average Course 2 scores (Figure 2) and differentiates between skills gained from disciplinary and interdisciplinary engineering curricula. A y = x line is plotted to indicate where plotted points would fall if the two scores were equivalent; points that fall above this line indicate a higher Course 2-A average score, while points that fall below this line indicate a higher Course 2 average score. Actual questions and average ratings of juniors and seniors according to major may be found in Table 7.

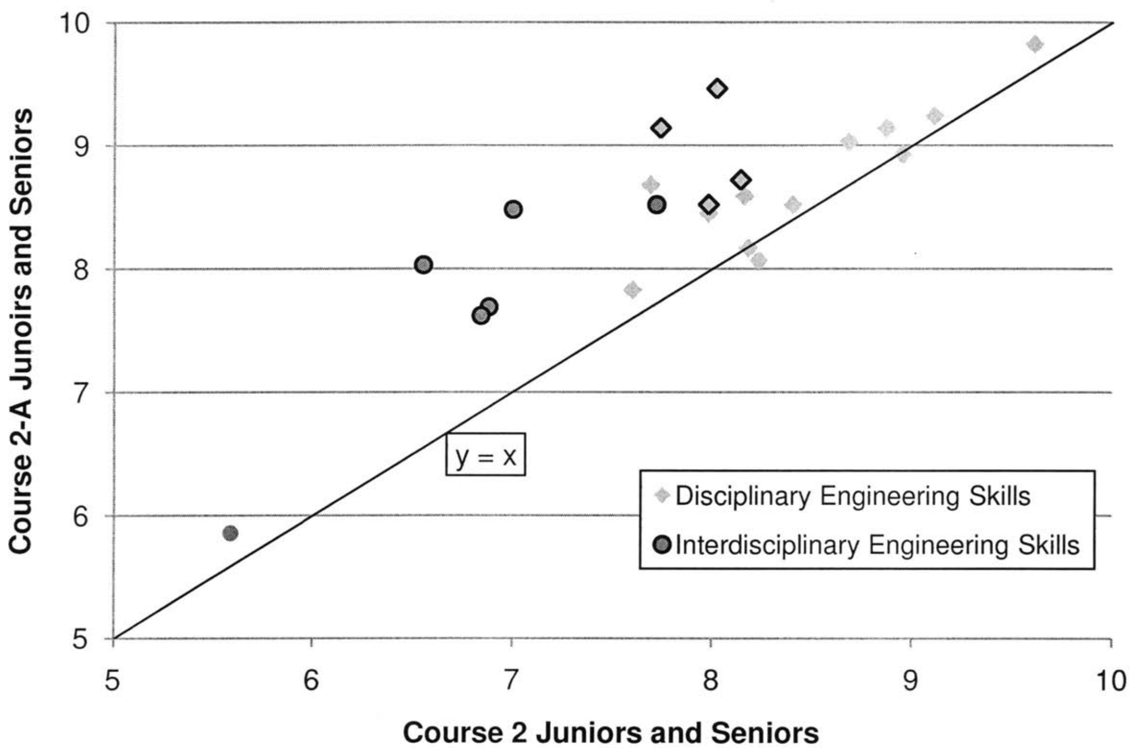


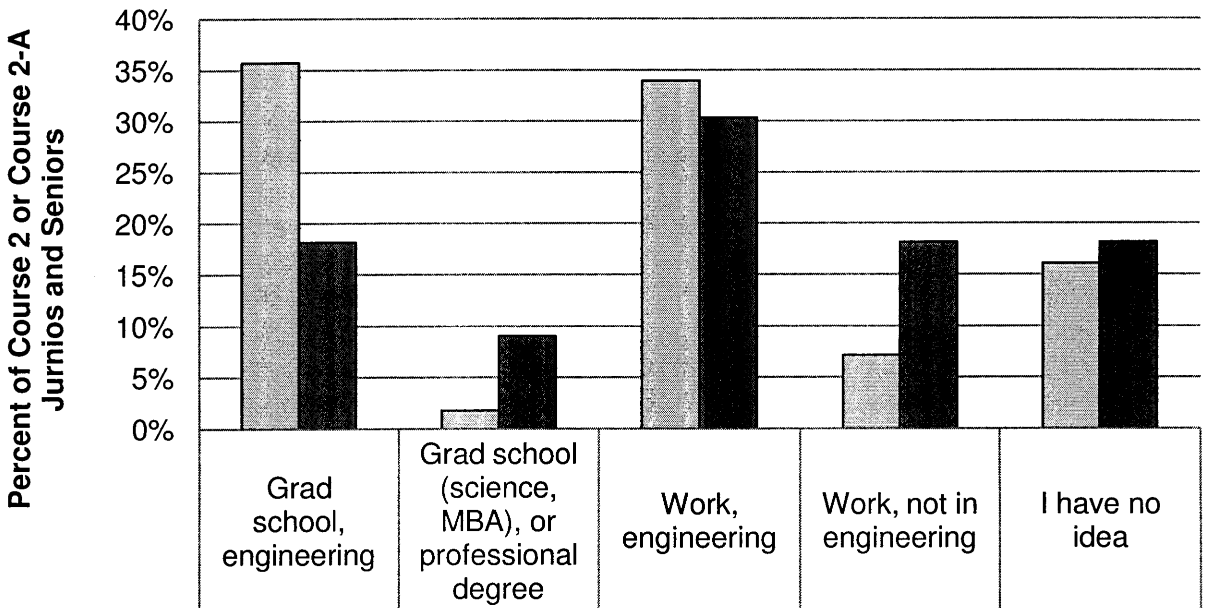
Figure 2. Question-by-question comparison of self-rated confidence level in engineering and non-engineering skills of Course 2 and Course 2-A juniors and seniors. Green diamonds correspond to engineering skills obtained from a disciplinary engineering education; blue circles correspond to skills obtained from an interdisciplinary engineering education. A plot of y = x is included as a reference. A black outline indicates skills that Course 2-A students gave an average confidence rating that was at least 1 point greater than the rating that Course 2 students gave.

Table 7. Mean perceived self-efficacy ratings. Course 2 (N = 66) and Course 2-A (N = 29)juniors and seniors rated their confidence in their ability to complete 22 tasks; a score of 1 corresponds to "not at all confident" and 11 corresponds to "extremely confident."

Skill type	Tasks	Mean rating	
		Course 2	Course 2-A
Engineering	Apply math in problem solving	8.87	9.14
	Apply engineering concepts in problem solving	9.11	9.24
	Recognize underlying technical principles in a complex problem	8.95	8.93
Design process and innovation	Use systematic design procedures and build something close to my specifications	8.68	9.03
	Understand what is new and important in a groundbreaking technical article	7.98	8.52
	Quickly grasp the limits of a technology well enough to use it	8.16	8.59
	Critically evaluate the merits of completing technologies well enough to choose the optimal one for a situation	8.18	8.17
Understanding social implications	Critically evaluate economic factors in making project choices	6.55	8.03
	Critically evaluate cultural factors in making project choices	6.88	7.69
	Carefully balance technical, economic, and cultural factors in making project choices	6.84	7.62
	Concretely use perspectives from several disciplines in solving complex problems	7.72	8.52
	Defend a point of view in a debate on a complex global issue	7.00	8.48
	Apply economic concepts in market analysis	5.59	5.86
Communication	Write effectively	8.23	8.07
	Write a concise letter explaining my career interests in a job application	7.60	7.83
	Write a concise 2-page report summarizing a project and outcomes for a supervisor	8.40	8.52
	Make a persuasive presentation that fits audience interests	8.14	8.72
	Convincingly talk about my most important work in an interview	7.98	8.45
Teamwork	Function effectively as a member of a team	9.61	9.82
	Make sure a team sets ground rules for a team will work together	8.02	9.46
	Give constructive criticism to a team member who is not performing well	7.69	8.68
	Set a precise project plan that maps out task order for a major project	7.74	9.14

4.4 Post-graduation plans

In an effort to understand the relationship between perceived self-efficacy and career goals, students were also asked about their immediate post-graduation plans and long-term career goals; only responses from Course 2 and Course 2-A juniors and seniors were analyzed (N = 89). Of these respondents, a comparable number of Course 2 and Course 2-A students did not have an idea of their plans (18% of Course 2-A compared to 16% of Course 2). A majority of Course 2 students planned on entering graduate school for engineering (36%) or work in engineering fields (34%). In contrast, half as many Course 2-A students as Course 2 students planned on entering graduate school for engineering (18% of Course 2-A compared to 36% of Course 2) while more than double planned on finding non-engineering related work (18% of Course 2-A compared to 7% of Course 2 students). Furthermore, a 9% of Course 2-A students indicated that they planned on pursuing higher degrees in non-engineering related areas (e.g. MBA, M.D.), compared to only 2% of Course 2 students. A summary of these results is shown in Figure 3.



	Grad school, engineering	Grad school (science, MBA), or professional degree	Work, engineering	Work, not in engineering	I have no idea
Course 2	36%	2%	34%	7%	16%
Course 2-A	18%	9%	30%	18%	18%

Figure 3. Post-graduation plans of Course 2 and Course 2-A juniors and seniors.
Course 2 students are shown in purple; Course 2-A students are shown in yellow.

When asked to rate their certainty about their long-term plans, almost 80% of Course 2 students (N = 55) indicated that they were not certain to moderately certain about their plans, contrasted to 63% of Course 2-A students (N = 33). Furthermore, 22% of Course 2 students indicated that they were moderately certain to very certain about their plans, compared to 36% of Course 2-A students. These results are summarized in Table 8.

Table 8. Certainty about post-graduation long-term plans of Course 2 and Course 2-A juniors and seniors.

Certainty	% Course 2	% Course 2-A
Not certain to moderately certain	78	63
Certain to very certain	22	36

5. Discussion

The goal of the present study was three-fold:

- To elucidate differences in student motivation, and whether or not this affects their choice of major.
- To identify differences in perception of Course 2-A between Course 2 and Course 2-A students, and whether these perceptions changed (positively or negatively) over time.
- To quantitatively measure students' perceived self-efficacy and how perceived self-efficacy affects a students' career plans.

A survey was designed and administered to the Course 2 and Course 2-A student body to solicit student feedback. To gain a better understanding of underlying motivating factors, students were asked to pick their top reason for choosing their major; Course 2- students were also asked why they chose their concentration. Perceptions of Course 2 and Course 2-A were determined by asking students to rate the opinions of their peers, the faculty, their families, and themselves of each major. In addition, students provided open-ended feedback on how their perception of both majors had changed over time. Finally, a self-efficacy survey was included to measure student perceived self-efficacy of 7 abilities related to engineering design. Students were also asked about their immediate post-graduation plans and their long-term career goals, and to rate their certainty about these plans.

The results of the survey and subsequent analysis revealed a close relationship between a student's career goals, motivation, choice and perception of major, and perceived self-efficacy (Figure 4).

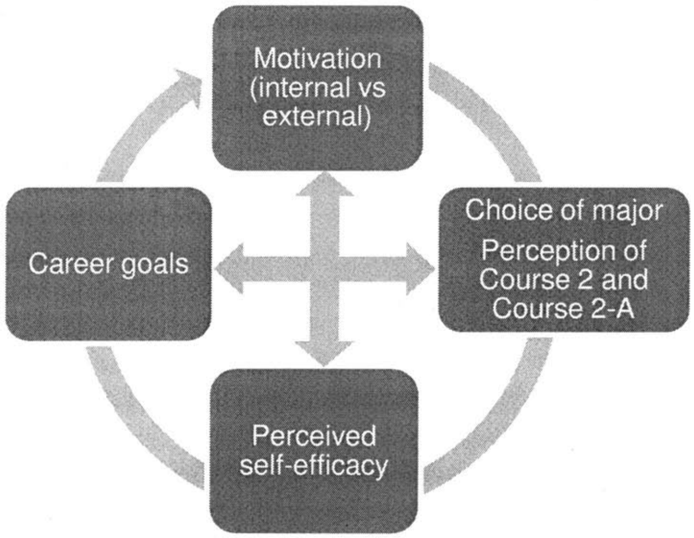


Figure 4. Relationship between a student's career goals, motivation, choice and perception of major, and perceived self-efficacy.

Although Course 2 and Course 2-A students were motivated by both intrinsic and extrinsic factors when selecting a major, the results of this study show that some differences in motivation still exist. Students majoring in Course 2 were not only cognizant of their general interest in mechanical engineering, but appear to have also been primarily motivated by external factors. For many students, the perception of the surrounding community, particularly the opinion of their peers, of the prestige and rigor of the Course 2 program was a source of external motivation to major in Course 2. In contrast, students in Course 2-A appear to have been primarily motivated by their desire to solve a specific problem, which ranged from alternative energy to international development; these students were intrinsically motivated to select an undergraduate program that would thoroughly prepare them for their future career.

Furthermore, the results of this survey indicate that over time, the perception of Course 2 students of Course 2-A remains or becomes more negative; however, the perception of Course 2-A students of Course 2-A remains or becomes more positive. Interestingly, the perceptions of both Course 2 and Course 2-A students of Course 2 became less positive over time. This is directly related to a student's source of motivation and choice of major: Course 2-A students are taking courses that directly relate to their career goals, and such, are more interested in and satisfied with the material. In contrast, the courses that Course 2 students are taking may not align with their interests and the curriculum is rigidly defined; as such, students find themselves less interested in the material covered by these classes.

Finally, Course 2-A students rated themselves significantly higher than Course 2 students on all abilities related to interdisciplinary engineering tasks. Course 2-A students indicated higher confidence in their abilities on 19 out of 22 categories; in 9 of these abilities, Course 2-A students rated themselves at least 1 point higher than Course 2 students, 5 of which were skills developed through an interdisciplinary engineering education. However, while the statistical significance of the difference between the average ratings of Course 2 and Course 2-A students was not tested, the difference is still worth noting. The high confidence level of Course 2-A students in their abilities may be accounted for their greater interest in their classes and motivation to learn the material well due to the direct application to their future career. In addition, their high confidence directly translated to greater diversity in their career plans; a higher percentage of Course 2-A students compared to Course 2 students planned on obtaining a professional degree (such as an M.D.) or working in a non-engineering field.

5.1 Effect of differences in motivation on choice of major

A higher percentage of Course 2 students compared to Course 2-A students chose their major because they were either interested in Mechanical Engineering as a discipline or because they received advice from their peers, faculty members, or their family. In addition, students who ultimately chose the Course 2 program indicated that their decision was also heavily influenced by their peers' negative opinion of Course 2-A. A possible explanation for this observation may be that Course 2 students are "discipline-focused" – that is, they have a clear idea of the discipline within which they want to work, but are unsure how they want to apply their knowledge in a broader sense. In order to fulfill the degree requirements, students take classes that they don't find as interesting or relevant to their future. These students are motivated by extrinsic factors to pass these classes, such as applying for a competitive job, regardless of their level of interest in the material.

In contrast, students planning to graduate from Course 2-A were attracted to the flexible requirements and their ability to focus their studies on topics that interested them. Furthermore, Course 2-A students were not significantly influenced by the negative opinion of their peers of Course 2-A. A possible explanation for this observation may be that Course 2-A students are "problem-focused"[3] – that is, they have a specific interest in an area related to mechanical engineering, such as product design, sustainable development, or international health. Their intrinsic motivation coupled with the flexibility of the Course 2-A requirements allows these students to take classes related to the problem that interest them since the skills and knowledge that they gain are directly applicable to finding a solution to the problem. For instance, a student who is interested in product design can now take graduate-level product design classes; another student interested in sustainable design and alternative energy can combine their mechanical engineering coursework with courses that fulfill an energy minor. The commitment of students to resolving these issues may also explain the minimal influence that various peer groups had on their decision to be Course 2-A.

5.2 Changing perceptions

Although a small percentage of students came to view Course 2-A more positively over time, the majority of students viewed Course 2-A more negatively over time. Several students commented that the Course 2-A program's requirements were less rigorous than the requirements of Course 2. Specifically, many Course 2 students felt that Course 2-A provided an "easy way out" for students who could avoid difficult core mechanical engineering courses and replace them with easier courses. In contrast, almost every Course 2-A student who responded viewed Course 2-A more positively over time and did not consider it as an "easy way out." Rather, students enjoyed the flexibility that the program offered which allowed them to take classes that were more aligned with their interests and more applicable to their future goals.

This is a stark difference from the perception of Course 2 students of Course 2; several Course 2 students noted that the material covered by core mechanical engineering classes were not applicable in industry. One senior pointed out that "we learn a lot of things that are important and completely useless in the real world" while another said that he "learned more about Course 2 from one independent project than all of the classes I've taken." A few students were also dissatisfied with the rigid requirements and their inability to take classes in other departments such as D-Lab.

This sentiment carries over to the perception of Course 2 of Course 2-A students. Students felt that Course 2 had too many requirements that, as one student stated, taught material which "would not be nearly as useful to my life after MIT (and I wasn't as motivated to study since I didn't have an interest in them)."

5.3 High confidence levels and career choices

Bandura noted that the higher a student's perceived self-efficacy, the greater number of career options they consider and the better they prepare for their future career; this relationship between self-efficacy and career choices was compared between students majoring in Course 2 and Course 2-A.

Course 2-A students reported higher confidence in their ability to perform every interdisciplinary engineering-related task compared to their peers enrolled in Course 2, and scored at least one point greater than their peers in 5 of the 6 tasks. This difference in self-reported confidence may be due to the fact that interdisciplinary curriculum allows Course 2-A students to gain experiences and skills that may not be emphasized by a Course 2 education. For instance, students completing a concentration in bioengineering may be asked to apply biology-related concepts to engineering situations; students completing a concentration in international development may be asked to consider more carefully the cultural and economic factors in engineering design than Course 2 majors.

Furthermore, Course 2-A students reported greater confidence in their ability to perform 13 out of the 16 "disciplinary" engineering tasks than their peers in Course 2. This result was surprising since it was expected that Course 2-A students would have less confidence than Course 2 students in their ability to perform these tasks since Course 2-A students take fewer mechanical engineering core requirements than Course 2 students.

The higher average self-efficacy ratings may explain why a higher percentage of Course 2-A students have non-traditional post-graduation plans – either finding non-engineering related work, or entering graduate school for non-engineering degrees (e.g. MBA, M.D.). In fact, compared to Course 2 students, a greater percentage of Course 2-A students is immediately working after graduation, and a smaller percentage is entering graduate school for engineering. In general, students who choose to enter graduate school receive further training in a subspecialty – something an undergraduate education may not have provided. Thus, Course 2 students may feel that they require further education in specific area of mechanical engineering before they enter the workforce; on the other hand, Course 2-A students have already focused their studies, and are immediately ready to enter the workforce upon graduation.

6. Conclusions

The purpose of this study was to investigate the growing trend in engineering education at MIT toward more flexible degree programs which allow students to not only gain the ability to approach complex problems with no clear disciplinary boundaries but also to develop a broader view of engineering in a global and social context.

It was found that Course 2-A students are primarily motivated by intrinsic factors, while Course 2 students are primarily motivated by extrinsic factors. Furthermore, Course 2 students perceived Course 2-A more negatively over time, while Course 2-A students viewed it more positively over time. Of note is that *both* Course 2 and Course 2-A students viewed the Course 2 curriculum more negatively over time. Finally, Course 2-A students rated themselves much higher than Course 2 students on all abilities gained from an interdisciplinary engineering education.

The results of this research do not say that Course 2-A is "superior" to Course 2; rather, they clearly indicate that the Course 2 and Course 2-A degree programs serve two very distinct student populations, and, thus, are both integral parts of the educational opportunities offered by MIT. They also suggest that a concerted effort must be made to combat both the dissatisfaction with the core Course 2 curriculum and the negative perception associated with Course 2-A.

Appendix: Course 2 and Course 2-A Student Survey

1. Your choice of major

Before you settled on your current major, we'd like to know which other majors you thought about.

1. Did you consider majors other than your current major?

- ○ Yes
- ○ No

2. If you considered other majors, which major(s) did you consider? (select all that apply)

- ☐ 1
- ☐ 2
- ☐ 2-A
- ☐ 2-OE
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10
- ☐ 11
- ☐ 12
- ☐ 14
- ☐ 15
- ☐ 16
- ☐ 17
- ☐ 18
- ☐ 20
- ☐ 21
- ☐ 22
- ☐ 24
- ☐ Didn't consider other majors

Other (please specify)

2. Course Background Questions

3. How did you find out about the major you chose? Please select the primary source.

- ◯ CPW
- ◯ Freshman Orientation
- ◯ Friends/word of mouth
- ◯ Parents
- ◯ Adviser
- ◯ Faculty
- ◯ Course 2 website
- ◯ MIT Course Catalog

Other (please specify)

[ ]

4. What was the top reason why you chose your major?

- ◯ Wanted to focus studies
- ◯ Friends were in the major
- ◯ Advice from peers/upperclassmen
- ◯ Advice from adviser
- ◯ Advice from parents
- ◯ Flexibility of requirements
- ◯ Interdisciplinary aspect
- ◯ No thesis required
- ◯ I like Mechanical Engineering as a discipline

Other (please specify)

[ ]

5. Did you switch from another major into your current major?

- ◯ Yes
- ◯ No

6. If you switched, what course were you previously majoring in ?

- ◯ 1
- ◯ 2
- ◯ 2-A
- ◯ 2-OE
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10
- ◯ 11
- ◯ 12
- ◯ 14
- ◯ 15
- ◯ 16
- ◯ 17
- ◯ 18
- ◯ 20
- ◯ 21
- ◯ 22
- ◯ I didn't switch

Other (please specify)

7. If you switched majors, why did you switch?

8. How would you rate your overall level of satisfaction with your choice of major?

	Not satisfied at all		Neutral		Very Satified
Satisfaction	◯	◯	◯	◯	◯

3. Course communication

9. What is your major (the one you plan to graduate from)?

- ◯ Course 2
- ◯ Course 2-A

10. How would you rate the level of communication between the course 2 or 2-A administration and students? (e.g. about the major, pre-reqs, requirements, etc)

	No communication		Moderately good communication		Strong communication
There is:	◯	◯	◯	◯	◯

11. How often do you meet with your course 2 adviser?

- ◯ Once a week
- ◯ Once a month
- ◯ Once a semester
- ◯ Once a year
- ◯ Once since declaring my major

Other (please specify)

____

12. How informed is your regular adviser about the course 2 or 2-A requirements?

	Not informed		Somewhat informed		Very informed
My adviser is:	◯	◯	◯	◯	◯

4. Perception of Course 2

13. To the best of your ability, please rate how the following people perceive 2 compared to 2-A

	Negatively		Neutral		Positively
Your peers	○	○	○	○	○
Your professors	○	○	○	○	○
Your family	○	○	○	○	○
Yourself	○	○	○	○	○

14. How did the perception of the following people affect your decision to be 2 instead of 2-A?

	Didn't affect		Somewhat affect		Greatly affect
Your peers	○	○	○	○	○
Your professors	○	○	○	○	○
Your family	○	○	○	○	○

15. How has your perception of course 2 changed over time?

16. How has your perception of course 2-A changed over time?

5. Course 2-A requirements and advising

For the Course 2-A graduating class of 2010+, the minimum number of second-level courses in a student's curriculum was changed from 3 to 2. In addition, the minimum number of units in a student's concentration was changed from 60 to 72 units.

17. Were you aware that the 2-A requirements have changed for the graduating class of 2010+?

- ◯ Yes
- ◯ No

18. How did you first find out about the Course 2-A requirement changes?

- ◯ This is the first time I've heard about the requirement changes
- ◯ Friends/word of mouth
- ◯ Regular adviser
- ◯ 2-A coordinator (Professor Hosoi)
- ◯ Other faculty
- ◯ Course 2 website
- ◯ MIT Course Catalog

Other (please specify)

[ ]

19. Do the changes in the course 2-A requirements affect your decision to be in this major? Please elaborate.

[ ]

20. How informed is your regular adviser about the course 2-A requirements?

	Not informed		Somewhat informed		Very informed	Don't know if adviser is informed
My adviser is:	◯	◯	◯	◯	◯	◯

21. Did you consider a minor in Course 2 rather than majoring in Course 2-A?

- ◯ Yes
- ◯ No

22. What is your 2-A concentration?

- ◯ Biomedical engineering and Pre-medicine
- ◯ Energy Conversion Engineering
- ◯ Engineering Management
- ◯ Nano/Micro Engineering
- ◯ Sustainable Development
- ◯ Precision Engineering
- ◯ Product Development
- ◯ Control, Instrumentation, and Robotics
- ◯ Mechanics

Other (please specify)

23. Why did you choose your 2-A concentration?

24. Which of the following Course 2-A track advisers have you met to discuss your concentration? Check all that apply.

- ☐ Biotrack: Prof. Peter T. C. So, ptso@mit.edu
- ☐ Energy Conversion Engineering Track: Prof. John G. Brisson, brisson@mit.edu
- ☐ Engineering Management Track: Professor Jung-Hoon Chun, jchun@mit.edu
- ☐ Nano/ Micro Engineering Track: Prof. Carol Livermore, livermor@mit.edu
- ☐ Sustainable Development Track: Amy B. Smith, abs@mit.edu
- ☐ Precision Engineering Track: Prof. Martin Culpepper, mculpepp@mit.edu
- ☐ Product Development Track: Profs. Warren Seering (seering@mit.edu) and Dan Frey (danfrey@mit.edu)
- ☐ Controls, Instrumentation, and Robotics Track: Professor John J. Leonard (jleonard@mit.edu)

Other (please specify)

25. If you switched majors, how many of your classes in your previous major counted towards your concentration?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ >5
- ◯ I did not switch majors

6. Perception of 2-A

26. To the best of your ability, please rate how the following people perceive 2-A compared to 2

	Negatively		Neutral		Positively
Your peers	○	○	○	○	○
Your professors	○	○	○	○	○
Your family	○	○	○	○	○
Yourself	○	○	○	○	○

27. How did the perception of the following people affect your decision to be 2-A instead of 2?

	Didn't affect		Somewhat affect		Greatly affect
Your peers	○	○	○	○	○
Your professors	○	○	○	○	○
Your family	○	○	○	○	○

28. How has your perception of course 2-A changed over time?

29. How has your perception of course 2 changed over time?

30. What are the most useful sources for support and/or questions about course 2-A? Please list.

31. What is the best way to communicate changes in and/or information about the 2A program?

- ○ MechE Undergrad Office
- ○ 2-A Website
- ○ Email to declared 2A students
- ○ Paper mail to declared 2A students
- ○ Advisor
- ○ Word of mouth

Other (please specify)

32. If there was a site dedicated to course 2-A, what information should be included?

7. Career goals and some info about you

33. At this point in time, what do you plan on doing immediately after graduation?

- ◯ Grad school, engineering
- ◯ Grad school, science
- ◯ MBA
- ◯ Medical school
- ◯ Law school
- ◯ Work, engineering
- ◯ Work, not in engineering
- ◯ I have no idea
- ◯ Other

34. What are your long-term career goals that your degree will help you achieve?

35. How certain are you about your long-term plans?

	Not certain at all		Moderately certain		Very certain
Certainty about plans	◯	◯	◯	◯	◯

36. Which of the following have you participated in? Check all that apply.

- ☐ UPOP
- ☐ Internship off-campus (other than UPOP)
- ☐ UROP
- ☐ Gordon Leadership Program
- ☐ D-Lab
- ☐ Public Service Center
- ☐ Student/ Fraternity/ Sorority Government
- ☐ The Tech/ Other regular publication
- ☐ Study Abroad program
- ☐ MIT sports team

Other extracurricular (please specify)

37. Graduation year

- ◯ 2010
- ◯ 2011
- ◯ 2012

38. Gender

- ◯ Male
- ◯ Female

8. Your abilities

Please rate your confidence at the CURRENT time in the following abilities:

39. What is your current level of confidence in your ability to complete the following tasks?

	Not at all confident					Moderately confident					Extremely confident
Apply math in problem solving	○	○	○	○	○	○	○	○	○	○	○
Apply engineering concepts in problem solving	○	○	○	○	○	○	○	○	○	○	○
Recognize underlying technical principles in a complex problem	○	○	○	○	○	○	○	○	○	○	○
Use systematic design procedures and build something close to my specifications	○	○	○	○	○	○	○	○	○	○	○
Understand what is new and important in a groundbreaking technical article	○	○	○	○	○	○	○	○	○	○	○
Quickly grasp the limits of a technology well enough to use it	○	○	○	○	○	○	○	○	○	○	○
Critically evaluate the merits of completing technologies well enough to choose the optimal one for a situation	○	○	○	○	○	○	○	○	○	○	○
Critically evaluate economic factors in making project choices	○	○	○	○	○	○	○	○	○	○	○
Critically evaluate cultural factors in making project choices	○	○	○	○	○	○	○	○	○	○	○
Carefully balance technical, economic, and cultural factors in making project choices	○	○	○	○	○	○	○	○	○	○	○
Concretely use perspectives from several disciplines in solving complex problems	○	○	○	○	○	○	○	○	○	○	○
Write effectively	○	○	○	○	○	○	○	○	○	○	○
Write a concise letter explaining my career interests in a job application	○	○	○	○	○	○	○	○	○	○	○
Write a concise 2-page report summarizing a project and outcomes for a supervisor	○	○	○	○	○	○	○	○	○	○	○

Make a persuasive presentation that fits audience interests	○	○	○	○	○	○	○	○	○	○	○
Convincingly talk about my most important work in an interview	○	○	○	○	○	○	○	○	○	○	○
Function effectively as a member of a team	○	○	○	○	○	○	○	○	○	○	○
Make sure a team sets ground rules for a team will work together	○	○	○	○	○	○	○	○	○	○	○
Give constructive criticism to a team member who is not performing well	○	○	○	○	○	○	○	○	○	○	○
Set a precise project plan that maps out task order for a major project	○	○	○	○	○	○	○	○	○	○	○
Defend a point of view in a debate on a complex global issue	○	○	○	○	○	○	○	○	○	○	○
Apply economic concepts in market analysis	○	○	○	○	○	○	○	○	○	○	○

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