Development of engineering professional abilities in a co-curricular program for engineering sophomores

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Introduction

Like many engineering schools, MIT found itself faced with the challenge of providing engineering students with an educational program that develops an ever-broader range of technical and non-technical abilities. With the primary curriculum already overloaded, the School took an alternative approach. Launched in 2002, the Undergraduate Practice Opportunities Program (UPOP) is a co-curricular program for sophomores that provides professional engineering experience and begins development of students' non-technical professional abilities at an early point in their undergraduate education. The UPOP program goal is to integrate three essential parts of effective learning: knowledge, experience, and reflection. UPOP consists of: 1) Knowledge 1- The program begins with an intensive week of engineering practice "boot camp" during the January intersession and is led by engineering and management faculty. Through active case-based and role-playing learning sessions, students gain practical knowledge and appreciation for interpersonal and presentation skills, leadership, professional ethics, organizational dynamics, product development, and statistical quality control; 2) Knowledge 2- In Spring, students attend alumni-led workshops on career development; 3) Experience- In Summer, students complete 12 weeks of employment where they will be able to realize UPOP's educational objectives; 4) Reflection 1- During the summer, students complete a structured journal that permits exploration of engineering teamwork, communication, and organization; 5) Reflection 2- In Fall, students meet to discuss their experiences with other students and faculty. Assessment and evaluation of the new program included activity feedback surveys completed by students, ability self-assessment surveys completed by UPOP students and a control group, employer review of student performance on internships for UPOP students and a control group, and collaborative review of completed student journals. Analysis of data revealed student improvement in many key non-technical professional abilities such as interpersonal and teamwork abilities, presentation, identification of customer needs as part of the product development process, and comprehension of organization dynamics and strategy concepts compared with the control group.

Background

During the past decade, changes in the organizational structure of business organizations have led to an increased need for well-rounded professionals. Professional competencies of communication, teamwork, and leadership, as well as the ability to work effectively in

complex business organizations have been identified as key in the contemporary workplace (Jones, 2003). Calls for improvement in the non-technical professional abilities of engineers led to revisions in the Accreditation Board for Engineering and Technology (ABET) accreditation criteria for engineering degree programs (Grose, 2004). The revised accreditation criteria of ABET EC 2000 recommend the development of technical and non-technical professional abilities as part of an undergraduate engineering education (ABET, 2001).

MIT alumni and senior survey data reflect the changing needs of the professional workplace. MIT's constituents supported the need for development of non-technical professional abilities of undergraduate engineering students. In a 2000 survey of engineering alumni who had graduated in 1994, alumni called for increased emphasis on "workforce skills." In addition, 1998 and 2000 Senior Exit Surveys revealed student desire for greater internship opportunities and interaction with engineering practitioners.

Designing a comprehensive, integrated curriculum that addressed the technical and non-technical ABET learning outcomes is a challenge. Often, many U.S. undergraduate programs, MIT among them, simply added new degree requirements in communication, professional ethics, or engineering and society that were not well integrated with the core technical engineering subjects. The result was an increasingly burdensome curriculum for both faculty and students (Grose, 2004).

Rather than continue to crowd the curriculum, the MIT School of Engineering sought an alternative approach that met ABET requirements and constituent needs. Developed in 2002, UPOP was developed to complement undergraduate engineering degree programs by providing students with an opportunity to both appreciate and practice engineering. The new program integrates academic knowledge with practical experience through a program that combines classroom and summer employment experience. Such integrated programs are considered to be an ideal curricular structure for improvement of undergraduate student professional abilities (Jones, 2003).

In order to best integrate academic and practical learning experiences, the program's learning model employs three essential components: knowledge, reflection, and practice. Students take part in active seminars that provide knowledge of professional engineering work. In summer, students take part in an engineering internship that enables them to take part in engineering professional practice. During the summer and in the following fall, students reflect on each aspect of what they have learned as part of their internship experience through a Student Journal and Reflective Group Discussions.

Every stage of the UPOP educational program experience involves active learning. Collaborative learning involving student groups and teaching facilitators motivates student involvement in UPOP learning activities (Myers and Jones, 1993). Use of student-centered, interactive instructional methods in engineering classrooms has been shown to improve student learning of engineering concepts (National Academy of Sciences, 2003).

UPOP Program

UPOP program provides students with opportunities to apply their classroom learning in off-campus real-world settings. The program objectives of UPOP are to:

- Provide broad segments of our students an opportunity to gain more awareness and appreciation of the realities of engineering practice.
- Help our students define and gain more meaningful off-campus summer job experiences, and to integrate these experiences with "classroom" learning.

The educational objectives of UPOP are to provide undergraduate engineering students the opportunity to:

- Apply knowledge of mathematics, science, and engineering principles and engineering design in a real world practice setting.
- Develop understanding and gain experience in interpersonal, team, and presentation abilities.
- Develop understanding and gain experience in the economic, legal, organizational and business realities that operate in a commercial company or government agency.
- Acquire an appreciation of the social, environmental and ethical implications of industry or government decision-making and practice.
- Gain experience in setting and carrying out career plans through resume writing, interviewing and networking training.
- Further develop as an individual, gaining self-awareness and appreciation of one's talents, competencies, and professional interests and preferences, and to understand how to leverage this awareness in an employment-based setting.

There are five key aspects of the UPOP program experience: 1) An "Introduction to Engineering Bootcamp" that takes place in the Winter Intersession of the undergraduate sophomore year; 2) a series of professional development seminars that train students in resume writing, interviewing, and networking; 3) summer internship; 4) completion of student journal during the summer internship; and 5) Reflective Group discussions in the following fall.

"Introduction To Engineering Bootcamp"

Students take part in a full week, 40 hour, "Introduction to Engineering Bootcamp" during the Winter Intersession of their sophomore year. Through very intentional and careful design of case studies and hands-on work, the UPOP curriculum addressed these core themes: Self-Awareness, Communication, Organizational Dynamics & Teamwork, Leadership & Collaboration, Applying Technical Skills, and Engineering in Practice: Process & Product Development, Commercialization.

Each day, student teams complete one or two case studies with the assistance of faculty mini-lectures with discussion and professional engineer facilitators. The structure of the course allowed students to fully interact with faculty members from across the School of Engineering and Management. Indeed, a key feature of the program is the use of professional engineers as student team facilitators. Each session and lecture encouraged students to think about the broad nature of engineering. For each case study, faculty and facilitators work with student teams in determining key case issues, and through role playing or discussion, determining decisions or other actions. All student groups gathered together at the end of each case study completion to discuss what each team had found.

The overall framework of the course gave students a moderately deep learning experience in selected capability areas important to engineering practice. Below are some specific examples of case studies, with role-plays, students undertook.

- Sample Communication Case Study excerpt: "Times are hard. You join an internet start-up company as a programmer during the Internet boom, but now your stock is selling for $.53, down from a high of $289. To add to your problems, the company is considering out-sourcing the research and development division to which you belong, laying off all the programmers. You are attending a meeting of managers that are either a group of nerds, bean counters, space cadets, or touchy-feelies (depending on which audience your group is assigned). You and your teammates have to convince them in a three-minute presentation of your position on the possible outsourcing. The message must address your target audience to convince them this action would be a mistake."

- Leadership and Collaboration Case Study excerpt: "You are assigned to one of three companies – MP3 Player Inc., Mountain Bike Inc., and Personal Digital Assistant Inc. You need to get to know what your customers want in the products you're developing, and surveying needs to be done. Each team member has to conduct five interviews, asking how he/she uses the product, his/her likes and dislikes about the product, and what suggestions he/she has for the product. The next day, you will have to collaborate with your team members to rank the top three improvements that could be made and presentations to the management will then follow."

- Business Strategy Case Study excerpt: "You are presented with a list of six industries: Confectionary, Diapers, Laptops, Pharmaceuticals, Ion Implantation Equipment, and Ultrasonic Flow Meters. Within three separate exercises, you need to decide which of these industries is investment-worthy. You need to collaborate with your team to rate the uniqueness of the industry, the potential for return on invested capital, the possible gross product, and the complementary assets of the firm. You will also rate the degree do which forces like rivalry, threat from entrants to the industry, substitutes for the product and attractiveness of the industry affect the firm's ability to make profits."

Professional Development Seminars

In the spring, students attend a series of brief professional development seminars, which are led by MIT alumni. Many alumni volunteer to coach UPOP students on issues critical to professional success, such as resume writing, interviewing, networking, navigating the recruiting process, and making the most of internship experiences. In addition to making presentations and leading discussions with students, both formally and informally, the alumni administer mock interviews and critique students' cover letters and résumés. In addition to giving UPOP students crucial practice and inspiring their confidence, the seminars are, in fact, real-life professional experience. Sometimes the natural networking the seminars facilitate even leads to valuable professional and personal connections, resulting in internships and genuine camaraderie amongst undergraduate students and alumni.

Engineering Internship

While all components of UPOP contribute to the growth and achievement of participating students, the actual professional practice experience is the core of the program. The UPOP Engineering Internship consists of ten to twelve weeks of employment at organization where the students can fully realize the program's educational objectives.

To ensure the highest quality internships and to further guide students in meeting program learning objectives, UPOP program staff either discuss the internship by telephone with students or, wherever possible, visit them during the summer. Often this form of contact enables young engineering students, many in their first professional work position, to discuss and brainstorm internship hurdles.

Student Journal and Reflective Group Discussions

Students deepen their understanding of non-technical professional engineering abilities through completion of a Student Journal during the summer and by taking part in Reflection Group Discussions in the following fall.

Student Journals, which students complete in three parts during the summer, contain structured questions that permit engineering students to reflect on their internship experience. Closely following the UPOP program learning objectives, and drawing on UPOP seminar material, the questions permit students to continue to make connections between academic material and their own professional experience. The journals continue to use role-playing to ensure that students view engineering work from various professional perspectives. The journals require students to analyze their internships from the perspectives of both an employee and a senior manager, thus encouraging them to see the big picture. They must also answer fundamental questions regarding their organization's structure, business operations, and employee experience. Appendix A contains a sampling of the Student Journal format.

As part of UPOP students' exit interviews when students return to MIT, UPOP staff collaboratively review students' journal responses with individual students. As part of the interview, the staff discusses each student's journal entries in terms of professional abilities or other factors that enabled or hindered success of the summer internship experience. With the help of UPOP staff, individual students are able to identify key areas for improvement.

The Reflection Group Discussions in the following fall permit students to share their internship experiences as a group with peers. Student groups of 5 or 6, with a professional engineer as facilitator, discuss key issues involving their work organizations, or interpersonal or teamwork, or professional engineering design teams.

Student Participants

Begun in the 2001-2002 academic year, the program has just completed its second year. All sophomores enrolled in the MIT School of Engineering were invited to participate in the co-curricular program. Enrollment in the winter intersession program was limited to 80 out of the, roughly, 600 students in the school in the first year. Of these 80 students, 55 received and completed summer internships. In the 2002-03 academic year, enrollment in the winter intersession was increased to 130 sophomores. Of these 130 students, 80 received and completed summer internships.

Program Evaluation and Assessment of Learning Goals

In order to ensure that the program's learning objectives are being met, several methods are used to evaluate the program and assess student learning of the UPOP combined academic/ internship program (Jones, 2003). At the end of the winter intersession program, students complete a feedback survey that reviews the overall quality of the program, as well as the quality of faculty teaching of each case study, teaching facilitators, and case study content.

In its two years of existence, the UPOP program staff has used the student feedback to carefully improve the program. For example, case studies that did not support learning objectives were either discarded or rewritten. Overall, however, the program has met a crucial need in student's undergraduate engineering educational experience. In the written feedback survey completed by students at the end of the winter intersession program, students have given very high ratings for this segment's overall quality. Seventy three percent of the 77 participating students gave the highest rating of 3 (scale 1=poor and 3=excellent program) for the 2001-02 session while 87% of the 130 participating students gave the highest rating of 3 in 2002-03 session.

Students felt that the program improved their preparation for a summer engineering internship (average rating of 5.7/7 in 2001-2002 where 1=poor preparation and 7=great preparation). Moreover, 2001-2002 students overwhelmingly rated the program as high in

its ability to improve their appreciation for the multi-faceted nature of engineering work (6.3/7 where 1=did not improve appreciation and 7=greatly improved appreciation). Students in the UPOP program gave similar high ratings during the 2002-2003 academic year.

In order to assess student learning of program learning objectives, several methods are used. First, both UPOP students and a non-participating control group of students were asked to complete a self-assessment of learning survey in the fall following their sophomore year summer. The carefully tested survey asks students to self-assess their ability to positively handle a series of professional situations that are related to each UPOP learning objective including: interpersonal and teamwork abilities, presentation, job hunting/ networking, business and strategy, and professional ethics.

In Fall 2002, 80 UPOP students, now engineering juniors, completed the survey after completing their summer internship. In addition, 143 non-participating engineering juniors were also asked to complete the survey. Tables 1a-1c present mean student responses for the UPOP and control groups for each category of ability improvement. The tables show that UPOP students have self-rated their improvement as higher on average for all abilities compared to the control group.

Table 1a. Comparison of Results of Control Group and UPOP Student Survey of Professional Ability Improvement: Interpersonal/ Teamwork and Presentation Abilities

PROFESSIONAL ABILITY	**Ability improved during sophomore year and following summer** Survey scale: Ability to positively handle this situation did not improve during my sophomore year and summer=1; slightly improved=2, moderately improved=3, greatly improved=4.	
	MEAN RESPONSE	
	CONTROL N=143	**UPOP N=80**
INTERPERSONAL/ TEAMWORK ABILITIES		
1.If I did not feel challenged by my job, I would just accept this as part of the job I've been given and not request more challenging assignments.	2.3	3.1
2.My supervisor has just given me a project goal, tasks, and deadline that are totally vague and unrealistic. I would just not sleep and get something done!	2.2	3.1
3.If I felt that there was a personal conflict between me and a coworker or my supervisor, I would ignore it and try to work anyway.	1.9	3.0
4.If my team was having a problem working together, I'd address the problem head on and talk to my team members about it.	2.1	3.0
PRESENTATION		
5.I have given some very good formal oral presentations to a class or group.	2.3	3.2
6. When giving a presentation, I tailor the presentation to fit my audience's interests.	2.2	3.5

Table 1b. Comparison of Results of Control Group and UPOP Student Survey Results of Professional Ability Improvement: Job Hunting/ Networking Abilities

PROFESSIONAL ABILITY	**Ability improved during sophomore year and following summer** Survey scale: Ability to positively handle this situation did not improve during my sophomore year and summer=1; slightly improved=2, moderately improved=3, greatly improved=4.	
	MEAN RESPONSE	
	CONTROL N=143	**UPOP N=80**
JOB HUNTING/ NETWORKING		
7. When I attend a meeting or presentation, I usually hang back with friends rather than try to network with alumni, faculty, or business people.	1.8	3.3
8. When I last looked for a job, I made lots of calls and emails to friends, alumni, and faculty to see if they knew of interesting opportunities.	2.0	3.3
9.When I last looked for a job, I worked hard to reframe my resume to meet potential employer interests.	2.1	3.3
10. Last time I wrote a job cover letter, I didn't really know how to write it to attract potential employer's attention.	1.8	2.7
11.When I went to my last job interview, I didn't really collect specific information about the company to prepare for the interview.	2.0	3.2
12.When I went to my last job interview, I studied up on the company and was ready to ask about its products or strategy.	1.9	3.1

Table 1c. Comparison of Results of Control Group and UPOP Student Survey of Professional Ability Improvement: Business/ Product Development/ Software and Professional Ethics Abilities

PROFESSIONAL ABILITY	Ability improved during sophomore year and following summer Survey scale: Knowledge of or Ability to positively handle this situation did not improve during my sophomore year and summer=1; slightly improved=2, moderately improved=3, greatly improved=4.	
	MEAN RESPONSE	
	CONTROL N=143	UPOP N=80
BUSINESS/ PRODUCT DEVELOPMENT		
13.I have working knowledge of the terms 'value added' and industry 'strategic position' and could keep up with work conversations that included such terms.	1.6	3.3
14.I have working knowledge of the engineering product development process and could apply it as part of my work.	2.3	3.4
15.If my job required me to find out customer needs for a possible new product, I don't have a clue how I'd collect customer information.	1.8	2.9
PROFESSIONAL ETHICS		
17.I have a strong appreciation for the difficult decisions that engineers must make that can involve professional ethics.	2.1	3.3

An employer evaluation form used for UPOP and non-UPOP students was also used. At the end of the 2001-02 UPOP cycle, employers of UPOP and non-UPOP internship students were asked to complete a written evaluation of student performance. The evaluation form was based on ABET learning outcomes. Table 2 presents the results of the employer evaluation. The table shows that employers' mean response for UPOP students was higher than non-UPOP students for the following abilities: function on a multidisciplinary team (1.2 for UPOP students versus 0.9 for non-UPOP students using a 2 point scale where 2=highest performance), communicate effectively in writing (1.3 for UPOP students versus 0.9 for non-UPOP students), and communicate effectively in oral presentation (1.2 for UPOP students versus 0.9 for non-UPOP students).

Table 2. Comparison of employer ratings of UPOP students and control group students after completion of summer internships (1)

	MEAN RESPONSE	
Student ability	**UPOP Employer Rating (N=37)**	**Control Group Employer Rating (N=59)**
1. apply math, science, engineering principles to solution of engineering problems	1.1	1.2
2. function on multi-disciplinary team	1.2	0.9
3. identify, formulate, and solve complex engineering problems	1.2	1.1
4. independently carry out an assigned project	1.0	1.0
5. communicate ideas effectively in writing	1.3	0.9
6. communicate ideas effectively in oral presentation	1.2	0.9

(1) Survey scale: ratio of student performance rating to importance of learning outcome for job performance. Higher ratio shows higher employer rating of student performance. Lowest possible ratio is 0.3 and highest possible ratio is 2.

Discussion

The UPOP program illustrates an example of a curriculum that enables the development of students' technical and non-technical professional engineering in a highly active learning environment. Assessment of student learning objectives shows that inclusion of this learning experience has significantly improved student development of non-technical knowledge and abilities including interpersonal, teamwork, presentation, career planning, business, and professional ethics.

After 2 pilot years, in which roughly one-fifth of all MIT engineering sophomores took part in the UPOP program, the program will commence program expansion. It is envisioned that nearly every engineering sophomore will take part in the program within the next 3-5 years.

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APPENDIX A.
UPOP JOURNAL QUESTIONS: PART 1
June: Corporate/ government organization fact-finding questions

Please complete these questions by the end of June, 2002.

These questions involve organization structure, products, customers, and supply chain facts about your company. The best way to handle these questions is to try to give a brief answer to each of them during your first few weeks on the job. You may need to do a little research in your company to answer these questions. To find the information, you might need to search a company website or two, or chat with your supervisor and co-workers. *In fact, it would make a great icebreaker with your supervisor and co-workers to chat about these topics*.

1. COMPANY ORGANIZATION AND MISSION

A. What are the primary products and/ or services provided by your company?

B. What is the organization structure of your company? Is it hierarchical or team-based? Are there separate hierarchical groups for marketing, R&D, manufacturing? Or are there teams focused on particular products that include engineers, marketing, etc.? You might answer this question by finding an organization chart of the company and adding it to your journal. You can also chat about this with your supervisor or co-workers.

C. If applicable, in what company organization group are you working this summer (Marketing, research and development, manufacturing, etc.)? What's your supervisor's title?

D. How does your group fit into the organization structure of the company?

2. PRODUCT/ PROCESS

A. If applicable, are you working on particular product (s) or processes as part of your job? If so, what?

B. If you are working on particular product(s) or processes, how might you describe the production/ distribution stream for that product? Where does your group fit into this stream? Who, in essence, are your group's 'customers'? Who does your group receive 'supplies' from? (Recall the IAP lecture on the beer production / distribution stream.)?

C. If you are working on improving a particular product(s) or processes, what primary technical or cost problem is your group working on? What approach is the group taking to solve the problem? Do you agree with the approach; would you suggest another approach?