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Engineering Outreach through College Pre-Orientation Programs: MIT Discover Engineering

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Section I: Introduction and Prior Art

Freshmen Pre-Orientation Programs (FPOPs) are activities for incoming college students that take place before the official start of Orientation. Common themes for FPOPs include the fine and performing arts, outdoor activities, and community service [1]. There is little or no data on how many such programs exist across the country, or when and where the idea for pre-orientation programs originated. It seems that they began appearing in the mid 1990's and are becoming more common over time.

FPOPs can be powerful outreach tools for incoming college students and provide an exciting introduction to the field of engineering. The benefits reach not only the first year students, but also the upperclassmen who help to run the programs and the departments that sponsor them. They complement some of the more common strategies used to enhance the freshman experience, improve academic performance, increase enrollment, and improve retention in STEM fields including pre-college summer programs [2-4], introductory courses offered during the first semester of the freshman year [5-8], and freshman advising seminars [8]. Academic FPOPs provide many of the same benefits as the more traditional programs, without requiring a large time commitment from the students or changes to the curriculum. Despite these advantages, academic FPOPs are still relatively uncommon and the authors are aware of only one STEM themed FPOP outside of MIT [9].

A family of three engineering FPOPs was developed at the Massachusetts Institute of Technology: Discover Ocean Engineering, Discover Mechanical Engineering, and Discover Civil and Environmental Engineering. This paper will discuss the basic format for these engineering pre-orientation programs, the goals and benefits of these programs, the details and success of these programs, and the future of similar programs at MIT and across the country.

Section II: Origin and History of Engineering FPOPs at MIT

MIT offered its first general interest FPOP in 1996. Two years later, development began for Discover Ocean Engineering (DOE). The program was created by Dr. Thomas Consi as part of an effort to raise the profile of both the ocean engineering department and the field among undergraduates. A pilot program for DOE was first offered as a freshman seminar course in the spring of 1998 [10] and the first pre-orientation session of DOE was offered in August of 1998.

In December of 2000, M. K. Thompson suggested creating a mechanical engineering FPOP based on the DOE model to address declining enrollment in the department. Thompson received a grant to develop Discover Mechanical Engineering (DME) and to help other departments within the School of Engineering to create similar "Discover Engineering" (DE) programs. A pilot program for DME was first offered in January of 2002 during MIT's Independent Activities Period (IAP) and the first pre-orientation session of DME was offered in August of 2002.

Two other engineering FPOPs have been created based on the same model. Thompson worked with Linda Liang, then a junior in the Civil and Environmental Engineering department, and her team of undergraduate students to develop Discover Civil and Environmental Engineering (DCEE). DCEE was first offered in August of 2002. Later, she also advised the administrators and students who developed Discover Electrical Engineering and Computer Science (DEECS). DEECS was first offered in August of 2006. MIT now offers a total of seven general interest FPOPs and ten academic FPOPs.

Section III: Discover Engineering Program Goals

The Discover Engineering programs share four basic goals:

1. To improve the quality of the freshman

Abstract

Freshmen Pre-Orientation Programs (FPOPs) can be powerful outreach tools for incoming college students and provide an exciting introduction to the field of engineering. The benefits reach not only the first year students, but also the upperclassmen who help to run the programs and the departments that sponsor them. A family of three engineering FPOPs was developed at the Massachusetts Institute of Technology: Discover Ocean Engineering, Discover Mechanical Engineering, and Discover Civil and Environmental Engineering. This paper will discuss the basic format for these engineering pre-orientation programs, the goals and benefits of these programs, the details and success of these programs, and the future of similar programs at MIT and across the country.

Keywords: outreach, pre-orientation, first year

experience.

2. To expose students to the excitement and challenges of engineering.
3. To increase enrollment in the sponsoring departments.
4. To provide an enjoyable and memorable experience.

To improve the quality of the freshman experience, FPOPs should provide students with increased awareness of and access to resources, opportunities, help and support. They should also provide students with informal opportunities to ask questions which may lower stress and prevent unnecessary and unforeseeable problems. One of the easiest ways to gain all of these advantages is to start the academic year with friends and mentors from pre-orientation programs (freshmen, upperclassmen and faculty) for company, guidance and advice.

Exposing students to engineering and showing them that it can be fun and exciting is a powerful form of engineering outreach. During the program students:

- Learn about the field of engineering and what engineers do.
- Learn about the specific field of engineering of the sponsoring department and how it is distinct from, yet related to, other fields.
- Learn how engineering is built upon a common base of science and mathematics. This realization will motivate the students to do well in their first year fundamental math and science courses.
- Learn about research in general and specific research opportunities within the sponsoring department.
- Learn technical skills (machining, soldering, etc.) that could be applied to future research experiences.
- Get hands-on experience in the specific field of engineering of the sponsoring department.

Increasing enrollment is closely related to engineering outreach. Students may be reluctant to choose an engineering major because of a lack of information about engineering as a discipline or career [5]. Giving students the information necessary to make an informed decision about the best choice of major for them is likely to result in both higher enrollments and higher retention. Students may also be reluctant to declare an engineering major because of concerns that their peers have more experience, better academic preparation, or a larger engineering skill set as incoming freshmen. FPOPs

help students to gain the skills and confidence necessary to pursue their interests. "Hard sell" tactics should never be used; they may increase enrollment in the short term but will also result in lower retention, academic performance and student satisfaction. To some degree, increasing enrollment can be viewed as a measure of the success of engineering outreach activities instead of as a separate goal.

Providing a fun and memorable experience is closely related to improving the quality of the freshman experience and increasing enrollment. It is common for first year students to find that the quantity and difficulty of work in college is much greater than in high school. Students may become frustrated or worn out, especially if they do not understand how the material they are learning is applicable to their interests or their futures. FPOPs can give students context and motivation for their future studies and good experiences which may prevent them from changing majors before giving it a chance.

Section IV: Design of the Discover Engineering Programs

The Discover Engineering programs all have five components:

1. A hands-on project with a final event.
2. Meals with faculty, staff, alumni, graduate students and upperclassmen.
3. On campus engineering related field trips.
4. Off campus engineering related field trips.
5. Social activities, on and off campus.

A. The project and Final Event

The project gives students hands-on engineering experience and is perhaps the most important and empowering part of the Discover Engineering programs. It unifies the various aspects of the program, gives the students a goal for the end of the program and makes the discipline immediately accessible to the students. A project should be chosen so that it:

- Has educational value related to the sponsoring department.
- Can be completed within a reasonable amount of time.
- Requires tools that are readily available or easy to obtain.
- Assumes no prior knowledge on the part of the student.
- Is relatively inexpensive and very robust.
- Gives the students a sense of accomplishment.
- Can be used in a final event.

DOE students work in pairs to build Sea Perch Remotely Operated underwater Vehicles (ROV) [11]. On the final day of the program, the ROVs are equipped with underwater video cameras and deployed in either Boston Harbor or Buzzards Bay from the docks at the Woods Hole Oceanographic Institute. During DME each student builds a radio controlled soccer playing robot. On the final day of the program, the students use their SoccerBots to compete in a double elimination robotic soccer tournament at the Boston Museum of Science. Small teams of students in DCEE build design and build windmills and discuss the positive and negative environmental impacts of wind energy. On the final day of the program, students test their windmills in the MIT Wind Tunnel.

The choice and implementation of the project can be a complex task. The projects require a balance between the technical difficulty of the project and the time it takes for the students to complete their projects, and a balance between the amount of technical information given to the students versus the amount of fun they will have. Clearly full lectures are not appropriate in these venues, but students should have an overall view of how the project relates to the broader academic field. It may also be desirable for the students to customize, personalize or design an aspect of the project. This promotes student ownership of the project and compensates for different experience levels and completion times. However, systematic engineering design methods, and not a trial-and-error approach, should be used for design projects. Finally, the decision to have students work individually or in small teams depends on the nature of the project, but group size should be kept to a minimum to ensure that every student gets to fully participate.

B. Meals

All meals are provided for the students and the program staff during the Engineering FPOPs. Meals provide an informal opportunity for the students to interact with faculty, staff, alumni, graduate students, upperclassmen and each other. Some meals have guest speakers who give short presentations on opportunities for first year students (in the sponsoring department or in general), talk about choice of major or life as an engineer in industry or academia. Other meals give the students a chance to ask questions or become comfortable talking to guests or each other. Gall et al. [12] and Pascarella et al. [13] both stress the importance of informal student-faculty interactions, especially

at meal times. Pascarella notes that “the initial interactions with faculty ... are the most influential” [13] so informal interactions with faculty and staff members during the FPOP programs may be a major advantage for students.

C. On campus field trips

During on campus field trips, students visit departmental research and teaching laboratories. They meet professors and graduate students and learn about research opportunities that are available both for undergraduates and professionals within the field and the department. Teaching facility tours give students an idea of the types of resources available for classes, extracurricular activities and clubs. Each program offers between 3 and 8 tours, each lasting no more than 20 minutes.

D. Off campus field trips

During off campus field trips, students visit local laboratories, engineering companies, industrial research facilities and engineering work sites. Students on tours meet practicing engineers, learn about the engineering industry and learn about internship and employment opportunities. Each program offers one or more off campus field trips.

E. Social activities

Social activities let students unwind, interact outside of an academic setting, and get to know some of the interesting things to see and do both on and off campus. These activities help familiarize the students with the school and its neighborhood. They also give students the time to build a circle of friends among their peers and the upperclassmen, faculty, and staff who will serve as a support group to help the students throughout their college careers. Each program offers a variety of social activities.

Section V: Discover Engineering Program Logistics

DE programs last four to five days, with students arriving the day before to check in and move into their residence halls. Activities usually start around 8am for breakfast and can go as late as 10pm. It is recommended that evening social activities be optional so participants can rest or have some unstructured social time before the next day.

DE programs can cost \$500 - \$1000 per student to run, but are offered free of charge to

incoming students. 11 students from DME and 33 students from DOE cited cost as a major factor in choosing an FPOP, showing that it is an important factor for many students.

Since close interaction between the participants and the program staff and guests is an important part of the program, the program should be limited to 40 students. This permits the students and staff to learn each others names and a make a personal connection. Experience in the programs indicates that this interaction is key and research by Gall et al. supports this. [12] DOE accepts thirty students per year and has them work on their projects in teams of two. DME has thirty two students per year who work individually but compete in teams of four. DCEE has thirty two students who work in teams of four. It is recommended that programs larger than 40 students be split into two smaller, separate programs.

While admissions for each program is slightly different, DE programs typically choose students who seem to be the most interested in the program and who will benefit the most from it. Admission is not dependent on choice of major and students with interests in all fields are welcome. The programs try to maintain an even gender balance for both the students and the program staff even if the gender balance of the applicant pool is skewed.

A program's staff typically consists of: a faculty advisor, a "super mentor", 6 – 10 student mentors, and runtime staff. A super mentor is a graduate student or experienced undergraduate who has significant program responsibilities. The mentors are undergraduate students, typically majoring in the sponsoring department, who guide the participants through all aspects of the program. The runtime staff members are any other staff members who help run the program and do behind-the-scenes work, but may not be able to commit an entire week to the program. DOE is a faculty run program with the super mentor serving as the assistant program director. DME and DCEE are student run programs, where the faculty advisor serves as a resource, but the super mentor is the head of the program. Student run programs tend to have more runtime staff members and are excellent project management and program development experiences for the upperclassmen involved. However, continuity may be an issue and the program quality and style may vary more than in a faculty run program. Both program management models have advantages and disadvantages and both have worked well.

Section VI. Success of Engineering FPOPs

Surveys, focus groups, enrollment data, and staff and mentor observations have been used to determine the success of the engineering FPOPs. All survey data discussed was taken from a compilation of the surveys for the first six years of DME (IAP 2002 – 2006) and seven years of DOE (1999-2005). Three types of survey questions were asked: questions with yes/no responses, questions with rating responses (student rating / maximum rating), and free response questions. Not all questions were asked every year and respondents did not necessarily answer all questions. All rating values listed represent averaged data. Percentages represent responses to yes/no and free response questions. MIT enrollment statistics were obtained from the annual president's reports [14] and the registrar's website [15]. National enrollment values for mechanical engineering and civil engineering and environmental engineering came from the American Society for Engineering Education college profiles and statistics [16]. Ocean Engineering numbers are based on ASEE profiles for universities offering either an SB in Ocean Engineering or a BS in Ocean Engineering. The gender statistics also come from the 2004 ASEE summary report [16].

A. Improving the Quality of the Freshman Experience:

Students in DME and DOE were asked if the program succeeded in providing sustained student / mentor interaction and giving the freshmen a chance to get to know upperclassmen. All but one student in DME and all students in DOE confirmed the success of student / mentor interaction. The students in DME were asked to identify the most important qualities in a student mentor. The most frequently cited qualities were: helpful (42 responses), friendly (39), experienced/knowledgeable (30), fun/funny (15), approachable (12) and patient (12). Similarly, the students in DOE cited: helpful (31), friendly (25), willing to answer questions and give advice (22), nice / kind (11), and approachable/open (7). This feedback provides a good set of criteria to be used for the selection and training of future FPOP student mentors.

Students in both programs were similarly asked if the program succeeded in providing faculty / student interaction. 96% of students in DME recalled having met faculty or staff members during the program but 35% requested more opportunities despite efforts to increase

student/ faculty interaction each year. 55% of students in DOE confirmed having sufficient opportunity to interact with faculty, but 27% requested more opportunity and 3% did not feel that they had enough interaction with the faculty. Although it may never be possible to provide the constant presence of faculty requested by the students, the programs were successful in providing sufficient opportunities for students to meet friends and mentors who could provide company, guidance and advice during the academic year.

B. Exposing Students to the Excitement and Challenge of Engineering

The laboratory sessions, on campus lab tours, and off campus field trips were all methods of exposing students to various interesting and exciting aspects of engineering. DME student survey responses indicated that the laboratory sessions succeeded in teaching new skills (4.11/5) and were enjoyable (4.33/5). The on campus tours improved understanding of the sponsoring field of engineering (3.94/5) and were enjoyable (4.05/5). The off campus field trips also improved understanding of the sponsoring field of engineering (3.65/5) and were enjoyable (4.25/5). DOE student survey responses overwhelmingly indicated that laboratory sessions and building the ROV was the element of the program with the greatest value to them. 99% of DOE students said they had been given enough opportunities to visit on campus laboratories, however 45% requested more lab tours. The Discover Ocean Engineering program offers two to three lab tours per year while Discover Mechanical Engineering offers up to eight lab tours per year. Based on survey responses, the students prefer a moderate number of tours (3 – 6) spread out over several days.

C. Increasing Enrollment in the Various Departments

After DME, students reported that they were more interested in Mechanical Engineering (4.0/5) and more interested in engineering in general (3.93/5). After DOE, students also reported that they were more interested in Ocean Engineering (5.58/7) and engineering in general (5.58/7). The average percentage of freshmen from DME that declared mechanical engineering each year was over 29% (~ 10 students / year) and the average percentage of freshmen from DME that declared a major in

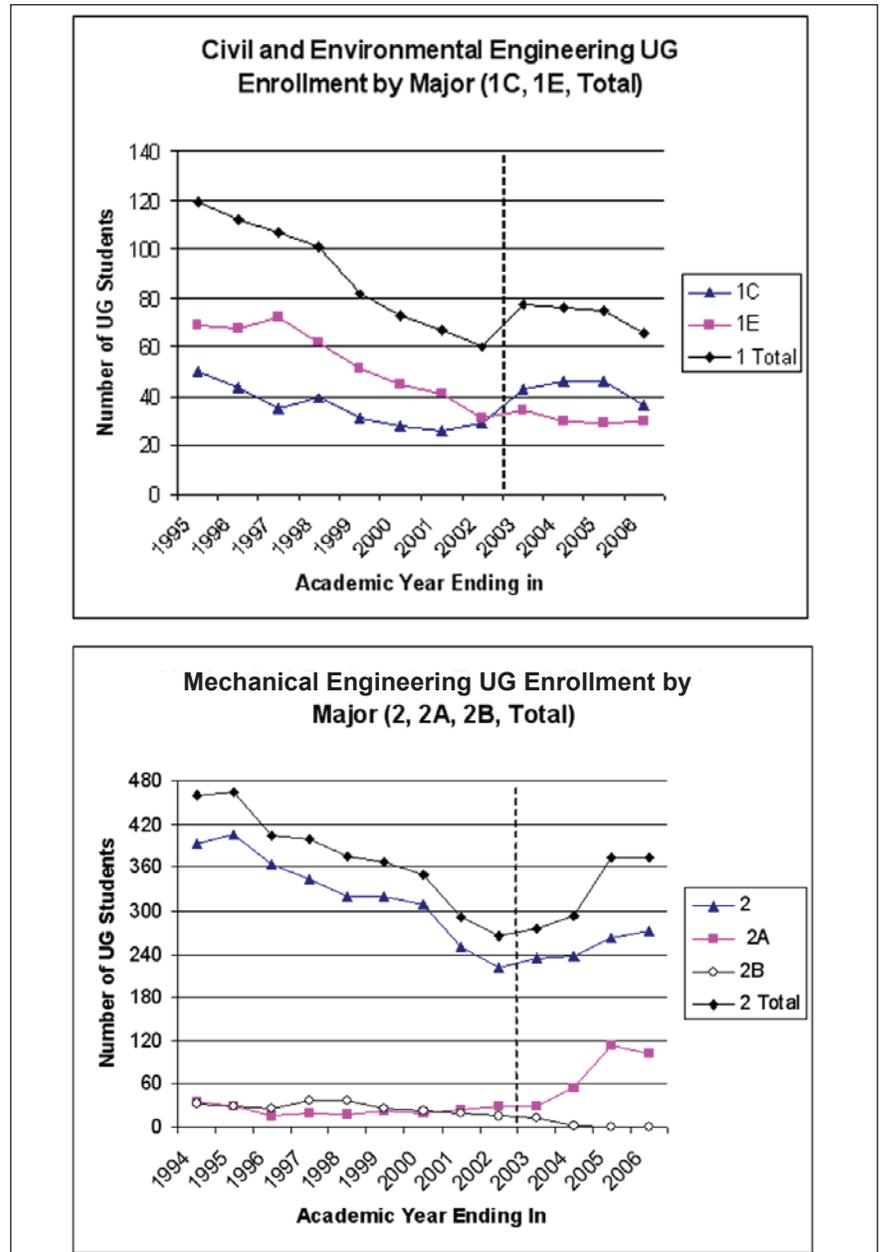


Figure 1. Civil and Environmental Engineering Undergraduate Enrollment by Major (top)

Figure 2. Mechanical Engineering Undergraduate Enrollment by Major (bottom)

the school of engineering was over 72% (~ 23 students / year). The number of students from DOE that declared a major in OE was closer to 10% (2 – 4 students / year). This shows that the direct impact of the programs on departmental enrollment is relatively small despite the positive impact that the programs had on their decision. However, the departmental enrollments all showed enrollment increases that correspond with the first offering of an engineering FPOP.

Figures 1, 2 and 3 show undergraduate enrollment by department (CEE, ME and OE

respectively) starting in the 1994-95 academic year and continuing through the 2005-06 year. The dashed line in each of the charts indicates when the first Engineering FPOP was offered. The undergraduate program in Civil and Environmental Engineering (course 1) has two major tracks: Civil Engineering (1C) and Environmental Engineering (1E). The undergraduate program in Mechanical Engineering (course 2) has had three major tracks in the past decade: Mechanical Engineering (2), Mechanical Engineering without specification (2A, ABET accredited in 2002), and the Mechanical Engineering Internship Program (2B, phased out by 2005). The undergraduate program in Ocean Engineering (course 13) merged with the Mechanical Engineering department in 2004. At the beginning of the 2005-06 school year, the track officially became 2OE. Enrollment in 2OE after the dissolution of the OE major is not considered in this paper.

In the 1998-1999 academic year, the enrollment for Ocean Engineering jumped from an average of 12 students for the four years prior to almost 18 students per year for the seven years after. In the 2002-2003 academic year, the enrollment for course 1E stabilized while the enrollment for course 1C increased and has been steady since. The enrollment for Mechanical Engineering (course 2 and 2A) has been steadily increasing.

The enrollment trends at MIT do not match the national trends, so it is reasonable to assume that both the decline and its reversal were a result of conditions at MIT. It is believed that the enrollment increases are the result of a paradigm shift in the departments. The departments all chose to address declining enrollment by making the department a more attractive and friendly environment for the student, including but not limited to the pre-orientation programs.

D. Provide a Fun and Memorable Experience

There are a number of indications that the pre-orientation programs succeeded in providing a fun and memorable experience. All but one student in DME reported having fun during the program. The DME students also stated that they would strongly recommend the program to members of next year's incoming freshman class (4.82/5). The DOE students also stated that they would strongly recommend the program to members of next year's incoming freshman class (6.7/7). The rate of freshmen in the program that return as staff and mentors is also

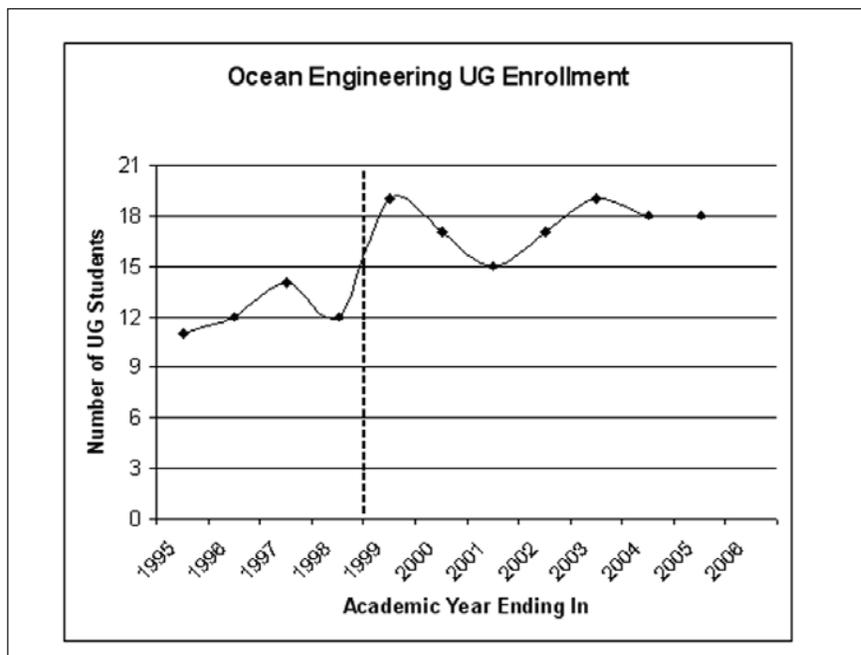


Figure 3. Ocean Engineering Undergraduate Enrollment

an indication of how successful the programs have been in providing a fun and memorable experience. On average, 49% of the DME staff and mentors had participated in the program as freshmen. However, only 67% of DME staff and mentors were Mechanical Engineering majors. This indicates that the program is a valuable experience for all of the students, staff and mentors in the program, regardless of their academic interests or choice of major.

E. Additional Benefits

In addition to the primary stated goals, the programs have succeeded in providing teaching, leadership, project design, and project management experience to the upperclassmen staff and mentors. It was hoped that the programs would increase interest in research in the sponsoring departments. Although students in DME reported that they were more interested in research in the mechanical engineering department after the program (4.08/5), there is no correlation between the FPOP programs and undergraduate research participation.

It was also hoped that the programs would increase the number of female students in the sponsoring departments in addition to increasing the total number of students. Enrollment of women both by percentages in all three departments have been stable over time and seem to be generally unaffected by enrollment fluctuations. However, the enrollments of women

in course 1C and in 2A have gone up significantly since 2002-2003. In course 1C, the average number of women enrolled has gone from 14.75% in 1998-2002, to 22.33% during the period from 2002-2006. In course 2A, the average number of women enrolled has gone from 8.33% in 1993-94 to 33.5% during the period from 2002-2006. The cause of the increase in enrollment of women in course 1C is unknown and may be due in part to the DCEE FPOP program. The increase in enrollment of women in course 2A is likely a result of the recent ABET accreditation.

VII. Future of Engineering FPOPs

When pre-orientation programs were first offered at MIT, up to 70 students were able to participate in the Freshman Leadership Program out of an incoming class of roughly 1,000 students. In August of 2006, nearly half of the students in the incoming class (508) were able to participate in 17 pre-orientation programs. The number of FPOPs at MIT is expected to continue to increase until there are enough pre-orientation programs for every incoming freshman to participate in if he/she desires. Of the new programs introduced since 2002, all but two have been academic FPOPs. It is the authors' belief that the Engineering FPOPs will continue to be offered as long as there is interest among the incoming freshmen because of the benefits to the first year students, to the upperclassmen that help to run the programs and to the departments themselves.

VIII. Conclusions

The basic format for three engineering freshman pre-orientation programs at MIT have been discussed and shown to accomplish the stated goals of the programs. By combining a hands-on project with tours, field trips, meals, and social activities, the programs are able to:

- Improve the quality of the freshman experience.
- Inspire students to careers in engineering.
- Increase student interest in the sponsoring departments and their respective fields.
- Contribute to increasing enrollment in the sponsoring departments.
- Provide a fun and memorable experience.

The ideas and outcomes of our engineering FPOP programs are both useful and desirable to engineering education in general. The relatively simple format of the programs can be

easily implemented and adapted to engineering programs across the country and around the world.

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