Preparatory summer "Introduction to Engineering: Mission to Mars" course for incoming minority engineering students at the University of Michigan

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Abstract

This paper describes and evaluates the preparatory summer "Introduction to Engineering" course offered as part of the Professionals-in-Training Program (PTP) at the University of Michigan College of Engineering (CoE). The Professionals-in-Training Program is one of three summer Bridge programs, sponsored by the Minority Engineering Program Office (MEPO), which target students in groups that have been historically underrepresented in the College and others who might face particular obstacles in coming to the College. These Bridge programs encompass the Ford Motor Company Summer Engineering Institute (Ford SEI) and are designed to facilitate the successful transition from high school to college for students coming in with various levels of academic preparation. Specifically, these courses preview and prepare incoming engineering students for the freshman academic experience by offering classes in computer programming, math, physics, and Introduction to Engineering, the latter focusing on engineering problem-solving, team work, and technical communication skills.

This paper first describes the University of Michigan College of Engineering MEPO organization and goals, with a focus on recruitment, retention, and pre-freshman programs, and includes several years of longitudinal data. Secondly, it briefly describes the focus, goals, structure and outcomes assessment of the "Introduction to Engineering" course at the University of Michigan. Finally, it details the specific aspects of the "Introduction to Engineering: Mission to Mars" course developed and offered as a summer preparatory course and discusses changes which will be implemented in future class offerings as a result of student assessment and feedback data.

1 Introduction

In 2003, a "Mission to Mars" theme was chosen by the CoE Ford SEI instructors for the PTP Introduction to Engineering course in order to incorporate the widest possible number of engineering disciplines. The specific focus was the cost-effective design of the life support systems, including air supply, water supply and food requirements. The technical components included items such as mission design, crew size, oxygen demand and carbon dioxide production, and water demand and reuse. The previous year's theme dealt with bridge design, and many of the students incorrectly believed that the engineering concepts and approaches they learned from that theme would only apply to the design of bridges. Rather than try to convince the students of the wider applicability of the underlying engineering concepts, the instructors decided to choose a design theme which would clearly connect to a wide number of engineering disciplines and which would engender student interest through its inherent challenge and appeal.

2 Minority Engineering Program Office Description

The Minority Engineering Program Office (MEPO) is a major component of the U-M College of Engineering (CoE) diversity efforts. Its mission is providing leadership, implementing, facilitating, and promoting policies and services that positively affect the CoE environment and increasing the number of underrepresented minority engineering students who graduate with engineering degrees. To accomplish these goals, MEPO focuses its initiatives primarily around students, U-M faculty and staff, and industry. As a result, the office offers information, programs and services which support the academic, professional and personal development of students.

Retention of Incoming Engineering Students

The University of Michigan College of Engineering offers three summer bridge programs for newly admitted engineering students:

- Professionals-In-Training Program (PTP)
- Alliance for Learning and Vision for Underrepresented Americans (ALVA)
- Engineering Bridge

These programs, sponsored by the Minority Engineering Program Office, target students in groups which have been historically underrepresented in the College or who might face particular obstacles in coming to the College. These programs are designed to facilitate the successful transition from high school to college for students coming in with varying levels of academic preparation. The overall goal of these programs has been to increase the 6-year graduation rate and academic performance of underrepresented minority students in the College of Engineering. The longest program in existence, the Professionals-In-Training Program, has had significant impact on minority student success.

The Professionals-In-Training Program (PTP) is currently a 6-week bridge program, offered during the summer, designed to prepare incoming engineering students for their first year in the College of Engineering at the University of Michigan. This program currently hosts approximately 40 students and emphasizes academic, personal, and professional success through rigorous academic courses, skill development activities, and a variety of workshops, seminars, and enrichment activities. PTP participants reside on campus and interact in both academic and non-academic settings, with staff consisting predominantly of UM undergraduate and graduate students, staff, faculty, and alumni. All costs, with the exception of transportation to and from campus, are provided by the program.

Curriculum

In the PTP program, students are exposed to a technical curriculum consisting of daily classes in Mathematics, Computer Skills, and Introduction to Engineering. These courses are designed to prepare students for their entry-level courses by providing them a foundation of the requisite skills for those courses. The classroom instruction is supplemented with evening and weekend tutoring hours conducted primarily by engineering undergraduate students.

The Mathematics course is designed as an intensive study of pre-calculus topics which are critical for success in UM mathematics courses. The course is designed to help students improve their basic high school math skills while developing better quantitative reasoning and problem-solving skills. The course content and style is closely modeled after that of the UM introductory mathematics courses. In conjunction with the Mathematics class, each student is involved in a facilitated study group that incorporates instruction and practice in critical learning skills and teaches students how to operate effectively within a group.

The Computer Skills course introduces students to the UM computing environment and teaches them introductory programming skills. Students learn many of the word-processing, spreadsheet, and math applications that are utilized throughout their undergraduate experience. They learn about the various computing platforms on campus, learn to use the University's electronic messaging system, and are introduced to C++ programming.

The Introduction to Engineering course is modeled after the College's Engineering 100 course, which is required for all engineering students. Students are presented with an engineering problem, then plan a strategy, gather information, analyze data, and produce a formal presentation of their team solution. The course places a heavy emphasis on technical communication skills and teamwork skills and teaches students basic project planning techniques. This paper focuses on a detailed description of one version of this course.

Overall PTP Program Effectiveness

The impact of PTP from 1988 through 2000 has been measured in terms of graduation rate and first-year academic performance. Our studies of PTP impact have focused on two groups of students:

Group A*:	the lower approximately one-half to two-thirds of the incoming underrepresented minority student group, as designated by the UM admissions process, based upon high school profile data
Group B:	the top approximately one-third to one-half of incoming underrepresented minority students, as designated by the UM admissions process, based upon high school profile data

**Does not include Engineering Bridge Program students beginning in Fall 2000*

Graduation Rates

The following tables show 6–year graduation rates for PTP students and non-PTP minority students for each cohort group from 1988 through 1994 categorized into Groups A and B:

This data shows that among Group B admits entering UM College of Engineering from 1988

6-Year Graduation Rates and SAT Math Scores: PTP vs. non-PTP

		1988 Fall Cohort		1989 Fall Cohort		1990 Fall Cohort		1991 Fall Cohort	
		Group B	**Group A**	**Group B**	**Group A**	**Group B**	**Group A**	**Group B**	**Group A**
Grad.	**PTP**	66.7%	44.7%	70.6%	50.0%	71.4%	46.2%	55.0%	33.0%
rates	**non-PTP**	75.0%	16.7%	65.6%	31.8%	61.1%	21.7%	62.0%	26.0%
Math	**PTP**	600	515	628	556	641	529	602	563
SAT	**non-PTP**	662	577	620	531	627	542	654	542

		1992 Fall Cohort		1993 Fall Cohort		1994 Fall Cohort	
		Group B	**Group A**	**Group B**	**Group A**	**Group B**	**Group A**
Grad	**PTP**	55.0%	36.0%	50.0%	46.0%	47.0%	47.0%
rates	**non-PTP**	45.0%	30.0%	53.0%	48.0%	59.0%	19.0%
Math	**PTP**	609	545	605	547	638	550
SAT	**non-PTP**	628	579	629	575	619	530

through 1995, the 6-year graduation rate of PTP students has been comparable to non-PTP minority students. The major impact of this program has been among Group A admits. Among Group A admits entering from 1988 through 1995, the 6-year graduation rate of PTP students has substantially exceeded the graduation rate of non-PTP students for every cohort group except for 1993. This was true even when average SAT math scores for these students were significantly lower than their non-PTP counterparts.

First Year Academic Performance

The following tables show first-year GPA performance for PTP students and non-PTP minority students for each cohort group from 1991 through 2000. Among Group B admits entering UM from 1991 through 2000, PTP students had a first year cumulative GPA approximately equal to their non-PTP cohorts (except for 1998 where non-PTP students performed substantially better), even though the average SAT math scores for these PTP groups were generally lower than those of their non-PTP cohorts.

First-Year Cumulative GPA and SAT Math Scores: PTP vs. non-PTP

		1991 Fall Cohort		1992 Fall Cohort		1993 Fall Cohort		1994 Fall Cohort		1995 Fall Cohort	
		Group B	Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B	Group A
1st Year	**PTP**	2.80	2.43	2.73	2.62	2.72	2.38	2.89	2.54	2.63	2.45
GPA	**non-PTP**	2.78	2.27	2.68	2.42	2.77	2.33	2.77	2.10	2.77	2.30
Math	**PTP**	602	563	609	545	605	547	638	550	627	513
SAT	**non-PTP**	654	542	628	579	629	575	619	530	631	573

		1996 Fall Cohort		1997 Fall Cohort		1998 Fall Cohort		1999 Fall Cohort		2000 Fall Cohort	
		Group B	Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B	Group A
1st Year	**PTP**	2.75	2.25	2.81	2.46	2.47	2.25	2.65	2.56	2.72	2.24
GPA	**non-PTP**	2.70	2.15	2.78	2.37	2.91	2.22	2.65	2.36	2.63	2.14
Math	**PTP**	609	555	645	564	637	562	650	590	627	571
SAT	**non-PTP**	645	560	652	560	654	596	645	580	642	581

Among Group A admits entering UM from 1991 through 1998, PTP students had a first year cumulative GPA greater than their non-PTP cohorts for each of the years, with an average difference of 0.15. This also held true during the years when average SAT math scores for PTP groups were significantly lower then their non-PTP cohorts.

3 "Introduction to Engineering" Course Specifics

The Introduction to Engineering course is designed to introduce students to the concepts of engineering design and analysis via a course long design project. The course heavily emphasizes professional communication, in both oral and written forms, and group and team dynamics. The Introduction to Engineering course offered by the MEPO Ford Summer Engineering Institute (Ford SEI) attempts to mirror the student's first year class experience. Similar to other universities, the UM CoE Introduction to Engineering classes typically focus on engineering design, technical communication, and team building. The course grade is determined from a mix of group and individual work, and technical and writing assignments. Course deliverables include individual technical homeworks, individual writing assignments, and group written and oral presentations. The written assignments are often designed to incorporate conclusions from the technical assignments to replicate real world engineering work conditions. The entire course is threaded around the ultimate design project, and the technical content is usually motivated by the engineering needs of the design project. Integrated into this general class theme are additional themes of ethical and environmental responsibility.

Differences between the Ford SEI *course and the UM CoE course*

There are differences between the Ford SEI course and the UM CoE course. The Ford SEI course has between 20 to 25 students that meet daily for 6 weeks, while the UM CoE course has 100 students that have full lecture twice a week, has a small group discussion once a week with 20 to 25 students, and extends for 14 weeks. The Ford SEI keeps the students quite busy, with almost 90 percent of the standard 45 hour work week devoted to scheduled activities, while the standard UM CoE freshman course load is typically less than 40 percent of the work week. As a result, the Ford SEI Introduction to Engineering course has to schedule most of the team building exercises within the class period while the UM CoE course has the flexibility to direct students to participate in group building activities outside of class. In addition, the longer class time of the

UM CoE class allows for more extensive project development. The Ford SEI students stay in close quarters and have more opportunities for collaboration throughout the UM campus system, and receive extensive coaching, mentoring, and encouragement throughout their 6 week Ford SEI program. In some of the UM CoE sections, the course grade is a function of feedback provided by the other team members, but this is not the case in the Ford SEI course.

Similarities between the FSEI course and the UM CoE course

In both cases, teams with four or five students are formed using profiling data provided by student survey. Teams are generally put together by the instructors based on student dorm location, intended student major, and gender. Teams with just one female member are avoided to prevent the student from feeling overwhelmed.

In both the Ford SEI course and the UM CoE course, the students are given a technical design project that involves information gathering, technical analysis, and written and oral communication. Course grade is dependent on both group and individual work. Both the Ford SEI and CoE classes have themes that tie together course content – e.g. “Pizza for Engineers,” “Engineering for the Marine Environment,” or “Mission to Mars.”

4 Mission To Mars

The Ford SEI Introduction to Engineering course theme was chosen as a result of negative student response to the previous year’s theme of “Bridge Design.” Although the course covered a wide range of aspects including material selection, testing, and properties; rehabilitation and maintenance; and financial and reliability analysis, the students were turned off by the focus on a “civil engineering” project. The “Mission to Mars” theme was then chosen to explicitly link the course to as many engineering disciplines as possible. The students in the MEPO course learned from the experience of other Mars student projects on campus including the robust “Mars Rover” student team and the proposed Mars-focused senior capstone design course.

Michigan Mars Rover Team

The College of Engineering houses several active student teams including the Michigan Mars Rover Team. The Rover project is an extracurricular activity with all work done outside of class. The Team consists of students from most engineering departments and from all years (Freshman to Graduate level). Students on the team designed, fabricated, and tested the world's first manned Mars rover prototype called "Everest." Everest is based on an Army FMTV cargo truck and is designed to house 3 crew members in a pressurized environment while they travel up to 1000 km round trip to explore the surface of Mars. Everest was tested at a Mars analog site in Utah and a local Michigan rock quarry.

The team is researching and integrating the latest automotive and aerospace technology to develop prototypes that are more advanced. Students are highly motivated by the opportunity to gain experience on a large scale project, contribute to solving the complicated problems inherent in such a vehicle, and participate in the exciting goal of Mars exploration[1].

Mars Senior Design Class

Beginning in January 2004, the College of Engineering is offering a new multi-departmental senior capstone design course. The course, sponsored by the Jet Propulsion Laboratory (JPL) and NASA, focuses on Mars exploration. Students design and fabricate prototypes of components of a permanent robotic outpost for Mars.

A robotic outpost is the next step after the near-term robotic missions currently run by JPL. An outpost will include power and fuel generation, water mining, construction, communication, navigation, and scientific analysis capability. This infrastructure supports extensive robotic exploration as well as testing the infrastructure for support of future human missions.

The new course will be offered each fall and winter semester and each class will build upon the work done the previous semester to contribute to this multi-year project. Students will work closely with JPL advisors and will have the opportunity to participate in summer internships at JPL.

PTP ENGR 100 – Class technical subject outline

In order to somewhat narrow the focus; the theme was limited to the life support components of a manned Mars mission. The class was introduced to the following technical considerations. Each of these is described in detail in the following sections. Two highly detailed Caltech student Mars Society reports provided considerable background for the curriculum development[2,3].

1. Mission goals
2. Crew requirements, and resulting crew size
3. Mission duration
4. Average per person air, water, and food demand
5. Transportation costs
6. Drinking water costs
    a. Water recycling costs
    b. Optimization of mission water supply costs
    c. Reliability of drinking water supply
7. Atmospheric conditions
    a. Carbon dioxide buildup
    b. Oxygen consumption
    c. Biological verses chemical regeneration
8. Food consumption and supply
    a. Factors affecting nutrient demand
    b. Long term storage/degradation of food supply
    c. On-board biological food generation weight
    d. Stored food weight
    e. Waste management

Mission goals

The design constraints were a function of the mission goals, crew size, and length of round trip. The mission goals were important to discuss, as they would directly influence the crew abilities and size[4,5]. Among the objectives considered were the following (in no particular order):

- Search for water
- Investigation of agricultural soil use
- Geological investigation
- Search for life/fossils
- Investigation of habitation construction
- Psychological impacts of both the flight and the planetary inhabitation
- Physiological impacts of extended stay in weightless environments

During this portion of the class, we also discussed reliability and redundancy of mission critical components such as navigation and medical equipment, and potentially mission critical people such as navigators and pilots. There was considerable disagreement on whether the mission would be piloted by computers or humans, and the instructors had to make several clarifying determinations and decisions. Some mission goals involved studies which would affect the lengthy space flight, while other missions would occur on the planet surface. Several scenarios were presented which highlighted the importance of planning. Over the duration of several days, the class formed groups and presented short memos arguing for and ranking particular mission goals. Finally, a single set of mission goals was determined for the entire class to ensure uniformity of basic design criteria among the groups.

Mission duration

Mission duration was dependent on mission goals and the specific flight trajectory chosen. There were three potential flight trajectories, with three different flight and surface stay times. These mission trajectories were classified: conjunction, opposition, or direct. Each trajectory had different technological requirements, timelines and risk factors. For instance, the direct trajectory was the quickest transit of only 60 days limiting zero gravity and radiation exposure, but required the development of a new advanced propulsion system to obtain the required speeds[6]. Using current technology, the opposition mission had an overall shorter mission length of 640 days with reduced radiation exposure, but a short 30-day surface stay limited the potential scientific benefits of the mission. Alternately using a conjunction trajectory, the Mars surface stay is over 18 months, but total mission length is 910 days, resulting in potentially increased risks to the astronauts[7]. After the instructors led class discussion concerning the mission trajectory and duration, a single trajectory and duration was determined for the entire class to again obtain uniformity of basic design criteria among the groups.

Crew requirements and size

Both mission length and mission goals had a significant impact on crew requirements and size. The class also briefly discussed gender matters that could influence these kinds of extended-length closed quarter missions. The class discussed the risk of an insufficient number of crewmembers and compared it to the cost of too large a crew. Early in the course, each group was tasked with the responsibility of determining a crew size and presenting their argument to the class as a whole. The class then voted on a standard crew size to use for the rest of the project design. The crew size and mission length then determined the specific number of crew-days that would have to be supplied by the life support system, with a specific focus on the air, food, and water supplies.

Air, food, and water per person demand

Each group individually tackled the life support (air, food, and water) requirements for the pre-determined number of crew-days. Each group did research in the engineering library as well as online to document an average crew demand for these components. The instructors pressed the students to evaluate the difference between average demand and potential scenarios which would place extreme demands on the life support systems. For instance, physical exertion increases oxygen consumption. Further, the instructors had the students consider the potential role of recycling water and food within the closed environment.

Transportation costs

The students were tasked to research liftoff and transportation costs on a weight basis. They were able to find a wide range of costs, and so the class settled on an average value of $1,000 dollars per pound of launched material. The instructors emphasized that this was a very rough number, but that "ball-park" figures are often used in initial engineering estimates.

Drinking water

The instructors chose the optimization of drinking water cost as the focus of the life support system. The drinking water component could be supplied by a combination of physiochemical and biological treatment or could be supplied by transport of the required water volume. For this course, the students were given a recycling cost C_r which was assumed to be cost per recycle of the total water supply, i.e., if V gallons were brought along, and $3V$ gallons were required for the entire trip, then the cost of the recycling unit would be $3C_r$. The students then optimized the amount of water carried and recycled. Finally, the water demand was varied using a Monte Carlo simulation to determine the likelihood of running out of water under various demand scenarios. This simulation was performed individually by each student using an Excel spreadsheet.

Atmospheric conditions

The instructors focused the atmospheric supply requirements on oxygen demand and carbon dioxide generation. The student teams had to evaluate plant growth and bottled oxygen to supply oxygen demand, and had to evaluate biological and chemical methods of carbon dioxide scrubbing. The students were encouraged to consider using biological methods of atmosphere regeneration. A very significant aspect of atmospheric recycling is the conversion of O_2 to CO_2. Although many of them found that a typical growing plant formed oxygen faster than it scrubbed carbon dioxide, most students did not successfully solve the problem of carbon dioxide buildup and resulting toxicity.

Food consumption and supply

This section focused on food nutrient value and weight. The class briefly discussed storage of food voyages of long duration, and discussed the possibility of making breads or other foods while en route. The instructors attempted to focus this section on the storability, palatability, and nutrient content of the food supply since the literature had emphasized the importance of these criteria. However, the students did not devote significant time to this aspect of the life support system, likely due to the apparent "non-engineering" part of the project.

Class communication subject outline

Course assignments were a mixture of individual and team assignments, with approximately half of the course grade based on individual work, and approximately half based on teamwork. Most of the teamwork assignments were based on the team project work, while individual work included exams, brief assignments related to the project work, technical assignments and engineering ethics material. The course emphasized a combination of engineering and professional skills, including the roles of teamwork, ethics and communication in engineering work.

In the first week of class, the students were assigned to teams of four or five people. Each team collaborated on two formal reports for this class, one written and one oral. These reports were presented and argued to the entire class in two profession presentations. A variety of assignments were required, as described below. Some were related to the project and some were separate and stand-alone. Dates are provided as a means to denote course progress during the session. The first day of class was July 7, and the last day of class was August 13.

Assignment	**Date due**	**Description**
Email assignment	July 15	Students were required to send an email introduction to the instructors.
Team resume	July 17	Teams were required and meet and discuss their strengths and abilities, and then to make a brief presentation to the class regarding their team
Individual informal memo	July 22	Each student was to write a memo arguing for a ranking of potential mission objectives.
Research report	July 23	Each student was to use the Michigan library system to find a paper on life support in outer space missions, and to summarize it in a memo
Rough draft of project report	July 21	Each team was required to present a project proposal to the entire class.
Technical assignment	July 30	Each student was assigned a Monte-Carlo reliability analysis of the drinking water system to minimize risk of failure
Oral presentation	August 5	Each team presented their final design of life-support systems to the entire class.
Final written report	August 7	Written presentation of final design of life-support systems.

Projects were graded by the instructors for ranking purposes and general tracking of student improvement, but numerical grades were not shared with the students. Instead, written and oral feedback was given.

5 Feedback And Improvements

Student feedback

Feedback regarding the course was solicited from the students via email at the end of their first semester. Feedback was obtained from approximately 30 percent of the students, and covered a wide spectrum of topics. Selected comments are below.

> *"The best aspect was the group work. Was a nice introduction to the work that you do in Engineering 100. Not enough focus on some of the technical topics that Engineering 100 covers."*

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> *"The PTP ENGR 100 class was very engaging, informative and interesting. "Mission to Mars" was a very interesting theme and actually visiting a prototype Mars vehicle was captivating. Probably, more visits from engineering societies/clubs would have furthered the class's interest. Toward the end, everyone was exhausted, which led to the very-bland-mechanical-like presentations."*

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> *"I think the best aspects of the "Introduction to Engineering" class was the interesting topic. Personally, I'm interested in space and space travel, so the topic actually got me motivated to do work well and on time. Another thing I thought was a good attribute of the class were the memos and oral presentations. I just finished Eng 100 this semester and we had to present our final report to everyone. The technical writing aspect is also important because we had to write a progress report and a final report – combined the two assignments were 25% of our grade. So technical writing was really important in order to succeed in the class."*

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> *"The thing that could be changed is maybe more of a focus on systems and system thinking. The Engr 100 [Introduction to Engineering] section I was in focused heavily on that topic. Also, considering engineers are all about systems and how to manipulate them, I would recommend talking about that to some extent."*

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> *"I enjoyed the Introduction to Engineering class we had over the summer, except for the 8:30 start time. I think the best thing you did was simply getting all of us to start writing memos, doing presentations and using Excel. Having an adequate background with the memo format and excel gave me a leg up in my Engin 100 class. Also, knowing what I had to do for oral presentations helped a lot."*

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> *"The Mars mission concept was a good one, there just weren't enough resources on it. A more researchable (but still interesting) topic would help the class a lot.*

I'm not a big fan of researching in general, though it is a necessary skill, just not an enjoyable one. If you could throw in a little more engineering rather than researching, maybe if you could do an actual project or design rather than just look at sources online."

Student feedback confirmed the success of the course, but raised useful points to consider in improving the quality of the course. The students appreciated the technical writing component of the course, but thought it was somewhat tedious. The technical component of the course was interesting to the students, but they desired a greater design component and less analysis of existing articles and reports.

Instructor perceptions and feedback

The instructors felt that the engineering students did not appreciate the detailed analysis which was emphasized. Rather, it appeared that they would have shown a greater interest in a more basic engineering assignment, which emphasized a single objective, and only a few constraints such as optimizing the atmospheric control units. The quick pace of the course, with daily meetings, precluded significant out-of-class group work and resulted in a tired class. However, the intensive nature of the entire PTP program prevents significant changes of the weekly schedule in the current format.

6 Discussion

The CoE MEPO program's summer bridge courses have considerable evidence to support their positive impact on the retention and graduation of underrepresented minorities. The courses provide significant exposure to class content as well as condition the incoming students for the rigors of college life. The data do not consider student intent and motivation. Students who participate in the summer bridge programs might be self-selecting their participation to some extent. More likely, the summer bridge courses enhance student intent and motivation through their inclusive environment and fundamental engineering content.

The "Mission to Mars" design project was chosen as the theme of the PTP ENG 100 "Introduction to Engineering" design course to inherently include every engineering discipline. Although the engineering design process could be demonstrated quite adequately with a narrowly focused design theme, beginning students lack the emotional and educational experience to relate widely divergent topics. A design-oriented class focuses considerable student attention on the design theme, with a resulting "love-hate" relationship regarding the theme. For example, the previous year's class focused on bridge design, and the result was that students who did not plan to enter civil engineering generally did not fully appreciate the course. The "Mission to Mars" design project has elements which can appeal to every engineering discipline. Further, the specific details of the Mission to Mars design project help introduce the student to a wide variety of engineering considerations.

Considering the goals of this course, the instructors spent a majority of the class time with the broad aspects of the design criteria, but left the students substantial leeway to apply their own constraints. The overall results were satisfactory, but post-course student feedback and instructor assessment both indicated that this first iteration of the "Mission to Mars" design project had allowed the students too much freedom for their projects, and that the course should move back towards emphasizing a single objective with a few constraints. A potential design focus would be one such as optimizing the atmospheric control units.

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