ASSESSING THE EFFECTIVENESS OF AN INTRODUCTORY ENGINEERING COURSE FOR FRESHMEN

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Abstract *– A new "Introduction to Engineering" (E10) course for freshmen was introduced in the College of Engineering at San Jose State University in the fall semester of 1998. The course was designed to give students a taste of engineering through hands-on design projects, case studies in engineering failures and ethics, and problem-solving using computers. Students learn about the various aspects of the engineering profession and acquire a variety of technical and non-technical skills. The highlight of the course is a semi-annual, industry-sponsored, design competition. The paper discusses the content and the goals of the course, as well as some of the methods used in delivering the content. Moreover, the paper assesses the effectiveness of the course in meeting its goals based on (a) how much knowledge students gain in each component of the course, and (b) how much the course is changing students' attitudes towards engineering, both measured from the students' perspective.*

INTRODUCTION

The College of Engineering has offered an introductory course for freshmen (E10) since 1992. The course was originally part of the lower-division engineering core, which was required by all majors. It was a two semester-unit course (1 hour of lecture + 3 hours of lab weekly) and had the title *Engineering Processes and Tools*. The emphasis of the original course was mostly on computational skills through the use of spreadsheets (first LOTUS 1-2-3, later EXCEL) and MATLAB. In fall of 1997, a task force was formed with a charter to:

1. Establish a mechanism to monitor and continuously improve the effectiveness of E10 in achieving its goals.
2. Recommend a math prerequisite or co-requisite for the course.
3. Generate resources for faculty who teach E10, including:
    a. Textbooks to be used in all sections.
    b. Compilation of a library of hands on projects.
    c. Course materials (syllabus, handouts, notes, etc.)
    d. A list of best practices in similar courses at other institutions
4. Recommend ways to make the course more motivating to first year students and illustrative of the various engineering disciplines.
5. Post appropriate course materials on the worldwide web.
6. Consider the possibility of making E10 available more broadly to students from other majors in the University, or developing a modified course suitable for this purpose.

The task force convened for a year (1997-1998), reviewed syllabi and course materials from all sections of E10, as well as from similar introductory courses at other institutions, and recommended a new three semester-unit course (2 hours of lecture + 3 hours of lab weekly), expanded in scope, as well as in methods. The new course was given the title *Introduction to Engineering* and the following goals:

1. Educate students about the engineering profession and expose them to several engineering disciplines through problem solving for the purpose of providing information to assist them in their choice of major.
2. Give students a basic understanding of engineering methods, including experimentation, data analysis, and computer skills.
3. Introduce students to engineering design through a variety of projects.
4. Provide opportunities for students to practice communication and team skills.
5. Provide support in academic success strategies, personal and professional development.

The specific (and measurable) learning objectives for each goal are listed in [1]. One of the primary elements in the new course is the hands-on, design projects. Many institutions [2-6] have recognized the need to introduce hands-on, engineering design at the freshman level, for the following reasons:

- ABET EC 2000, criterion 3, states that engineering graduates must be able to design experiments (attribute b) as well as systems, components, or processes to meet desired needs (attribute c) [7]. Although most engineering programs include a formal two-semester, senior design experience, design like any other skill must be introduced early in the curriculum and practiced on a regular basis, if the students are to achieve the level of mastery prescribed in attributes b and c. Moreover, ABET EC 2000 standards specifically recommend the inclusion of design across the curriculum.
- Engineering schools have come under increasing criticism after World War II because they have overemphasized analytical approaches and engineering

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science at the expense of hands-on, design skills [8,9]. As the editor of Machine Design put it, *"Schools are being charged with not responding to industry needs for hands-on design talent, but instead are grinding out legions of research scientists…"* [10].
- Hands-on, freshman design projects teach students early on about the role of failure in successful designs [11-13].
- First-year design courses help attract and retain engineering students [14].
- A large percentage of engineering students are visual, sensing, and active learners [15] and it is necessary for them to see, touch and feel things before they can fully process engineering concepts. Hands-on, design projects are one of the best learning vehicles for these kinds of learners.
- Freshman design projects promote teamwork. There are two reasons why teamwork is important in undergraduate engineering education. First, research has repeatedly shown that students learn better when working with each other than when working in isolation or competing against each other [16-18]. Second, it forces students to practice team and small group communication skills, which are absolutely essential in the real world.

E10 is one of two courses required by all engineering majors, the other being Technical Writing (E100W). Approximately 1,000 students take the course every year. Most students take E10 during their first semester at SJSU, so the course is a critical instrument for increasing student retention.

COURSE CONTENT AND DELIVERY

The course has the following content components:
- The engineering profession
- Engineering design
- Engineering ethics
- Student personal and professional development
- EXCEL
- MATLAB

The introduction to the engineering profession actually encompasses the entire content of the course, as design and ethics represent two very important aspects of the profession. However, the first goal (and the first component) of the course focuses primarily on identifying the various types of engineers, their job functions, and the kind of problems they solve in the real world. The students solve simple engineering problems from each discipline analytically, experimentally, and computationally.

The introduction to engineering design takes place primarily through hands-on design projects [1]. Students work in teams to research, brainstorm, design, build and finally test and demonstrate their devices in class. Typically, students participate in two or three projects during the semester. The last project is common in all sections. The best two teams from each section (based on established criteria) compete in the final E10 design competition on the last day of the semester [1]. The first, second, and third place teams receive monetary awards, sponsored by industry.

Engineering ethics is introduced through case studies. Students work in teams and they are given a week to research a case study. Each team then presents their case in class. Following class discussion, all students prepare a short write up on each case study.

To meet the fifth goal (related to the fourth component of the course), students are introduced to the various types of student services available at SJSU and they are encouraged to join in the activities of their engineering professional societies. Moreover, they assess their strengths and weaknesses based on a variety of models and they develop an appreciation of their learning styles and personality types. This knowledge is important for two reasons. First, understanding their own learning process is an important step towards becoming lifelong learners. Second, they need to be aware of the different ways people learn and react to different situations, so that they can be effective team members.

EXCEL and MATLAB are used in the lab as tools for engineering problem solving, data analysis, and graphing.

STUDENTS' OWN ASSESSMENT OF THEIR LEARNING

At the end of the semester, students are asked to fill out a questionnaire and assess their understanding of the various components of the course content (table I). Students are asked to fill out two of these tables. In the first one, they assess their understanding of each component before taking E10. In the second one, they are asked for their input regarding their understanding of each component after taking the course. A value of (1) was assigned for a student response of *"no understanding"* and a value of (4) for a response of *"great understanding"*. It must be kept in mind that E10 students' background varies greatly in terms of skills and knowledge in each of these components. Consequently, an average gain of the order of 1.0 (or more) for a particular component is significant, as it implies that most students' knowledge increased by one level on the scale used in the questionnaire. Similarly, a gain of the order of 0.5 or less indicates that from most students' perspective, their gain in this particular topic was negligible. The results from 174 questionnaires collected in fall 2001

TABLE I
QUESTIONS FOR STUDENTS' SELF-ASSESSMENT OF THEIR KNOWLEDGE OF E10 CONTENT

Check one box in each row to rate your understanding of the following:	(1) No Understanding	(2) Little Understanding	(3) Some Understanding	(4) Great Understanding
1. The types of engineers and the kind of problems they solve.				
2. Engineering ethics.				
3. How to use mathematical modeling to estimate.				
4. How to write engineering reports.				
5. How to give engineering oral presentations.				
6. How to solve engineering problems.				
7. The engineering design process.				
8. How to work effectively in teams.				
9. Learning styles in general and your learning style in particular.				
10. What it takes to succeed in Engineering.				
11 What it takes to do well on exams.				
12. EXCEL				
13. MATLAB				

from 5 different sections, are summarized in figure 1. According to the students, E10 increased their understanding in MATLAB more than in any other area (gain = 1.59). Students also claimed significant gains in their understanding of design and ethics (gain = 1.21), report writing (gain = 1.19), and presentation skills (gain = 1.12), followed by their understanding of the various engineering disciplines (gain = 1.01), learning styles (gain = 0.97), problem-solving (gain = 0.92), EXCEL (gain = 0.89), what it takes to succeed in engineering (gain = 0.88), and lastly estimation and mathematical modeling (gain = 0.86). The lowest scores came for gains in team skills (gain = 0.62) and what it takes to do well on exams (gain = 0.45).

Some of these scores are not hard to understand. For example, most students are exposed to MATLAB for the first time in E10. Hence, claims of higher gains in MATLAB are to be expected. On the other hand, several students come to the course with significant knowledge of EXCEL. As a result, their gain in this area is less since it is customary for instructors to adjust their teaching to the level of students with no prior experience in the course content. The reported low gains in exam skills and team skills need to be addressed with appropriate changes in teaching methods. In both cases, more time must be spent in class discussing both of these topics. Regarding exam skills, one of the challenges is dealing with students' preconceived notions, such as *"my way of preparing for exams has worked well all these years, I don't need to change it now"*. Regarding team skills, students hold similar views, as indicated by the high understanding they claim, before taking E10. The data shows that even though students spend a significant amount of time working in teams in a variety of assignments, they need more guidance and coaching on acquiring the specific skills (conflict resolution, task delegation, decision making, etc.) needed to be effective team members.

CHANGING STUDENTS' ATTITUDES TOWARDS ENGINEERING

The "Attitude to Engineering Survey", developed at the University of Pittsburgh, is given to the students during the first week of classes and again at the end of the semester. The purpose of the first collection is to establish the general student attitudes towards engineering as a profession, before they have an opportunity to be influenced by the course.

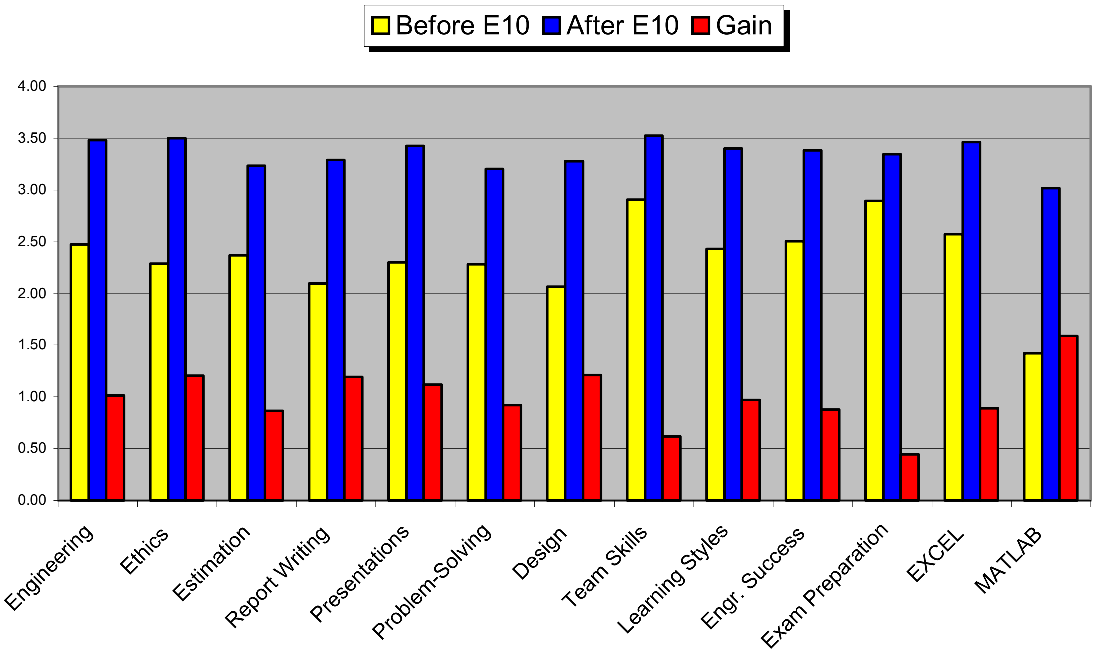

FIGURE 1.
STUDENTS' SELF-ASSESSMENT OF THEIR KNOWLEDGE ON THE VARIOUS COMPONENTS OF THE COURSE CONTENT

The purpose of the second collection is to measure the impact of E10 in changing student attitudes towards engineering. The results presented below are based on 514 surveys collected at the beginning of the semester and 399 surveys collected at the end of the semester during fall 2000, spring 2001 and fall 2001. For the purposes of this discussion, a change of 2% or less is considered negligible, a change between 3% and 5% is considered small, a change between 6% and 8% is significant, and a change of 9% or larger in any of the responses is considered large. The results of the survey are summarized in table II.

Although results vary from section to section (results from individual sections are not shown here), overall, students' attitudes towards engineering tend to be very positive before, as well as after taking the course. E10 seems to have virtually no impact on students' perception about engineering as an exciting (#2), challenging (#10) career and about the fact that engineers design products (#9) and make important contributions to our society (#6).

A small positive change occurs in students' perception about opportunities to be creative in their profession (#1), job security (#4) and professional prestige (#3). More significant positive changes appear in students' perception about career opportunities in engineering for women (#15) and minorities (#16). In addition, the course seems to have a significant impact in convincing more students that teamwork is an essential element in engineering work (#13).

The results in three of the statements (#5, 7, 11) are puzzling. The percent of students, who believe in two common myths about engineers (#7, 11), although small, seems to increase during the course. In addition, students' confidence on engineering salaries (#5) seems to decrease during the course. On the other hand, more students show preference towards engineering as opposed to science at the end of the course (#12), even though their confidence in pursuing an engineering career shows a slight decline (#14, 17). The last result is not surprising, since the course highlights not only the excitement of the engineering profession but also its challenges.

The most significant positive change as a result of the course is in students' perception that engineers are well-rounded people (#8).

CONCLUSION

The results from the two instruments presented in this paper, cannot possibly convey a complete picture of the effectiveness of E10, as they rely solely on the students' perspective. Additional information is needed, to ascertain the instructors' perspective and provide a more complete assessment. Nevertheless, they do suggest that E10 meets its goals, as outlined in the beginning of the paper.

TABLE II
SUMMARY OF STUDENTS' ATTITUDES TOWARDS ENGINEERING, BEFORE AND AFTER E10
Numbers show % of students who agree with each statement.

	Before E10	*After E10*	*Change*
1. Engineers have lots of opportunities to be creative.	0.74	0.78	0.04
2. Engineering seems like an exciting career.	0.71	0.69	-0.01
3. Engineering is a prestigious profession.	0.68	0.72	0.04
4. Engineers have secure jobs.	0.39	0.43	0.03
5. Engineers make good salaries.	0.74	0.68	-0.05
6. Engineers make important contributions to society.	0.80	0.81	0.01
7. Engineers are involved primarily with military and defense work.	0.10	0.15	0.05
8. Most engineers are well-rounded people.	0.17	0.27	0.11
9. Engineers design and create products.	0.67	0.65	-0.02
10. Engineering seems like a challenging career.	0.89	0.86	-0.02
11. There is little difference between engineers and scientists.	0.19	0.24	0.05
12. I would rather be an engineer than a scientist.	0.65	0.70	0.06
13. Most engineering is done in teams.	0.66	0.75	0.08
14. I hope to be an engineer someday.	0.90	0.83	-0.08
15. There are ample career opportunities in engineering for women.	0.51	0.57	0.06
16. There are ample career opportunities in engineering for minorities.	0.53	0.59	0.06
17. I think I have what it takes to be a successful engineer.	0.77	0.74	-0.03

In addition, the two surveys have provided useful information on the areas where the course needs improvement. For example:

- Team skills: In addition to offering opportunities for teamwork, students must be taught specific team skills, which must be assessed after every team assignment.
- Exam skills: The challenge here is to convince students that in order to do well on engineering exams, they need to start preparing well in advance and learn the material in depth (level 4 in Bloom's Taxonomy), so that they can carry working knowledge of the material in subsequent courses.
- Clearing misconceptions: Although the percentage of students who have misconceptions about the engineering profession (#7 and #11 in table II) is fairly small, more class discussion along with specific examples are needed to ensure that all students leaving E10 have a clear idea of where engineers work and the kind of work they do.
- EXCEL: To help more students gain more skills, lab instruction could be tailored to individual needs, so that students who come to the course with some knowledge of EXCEL can be challenged with more advanced problems.

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