Extended Abstract - Enhancing Student Learning and Success: First-year Engineering Program

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***Abstract* - This study reports on a piloted two-quarter first-year engineering course, Introduction to Engineering, which provides an early introduction to the engineering disciplines and design process. The course teaches basic skills such as CAD and microprocessor programing and the opportunity to design, fabricate and test a device constructed by teams of students. More pragmatically, the course provides students with the information regarding different engineering disciplines so that they can make a more informed decision as to whether engineering is the right major. Furthermore, students learn how to work on teams and lead design teams so as to help the students develop leadership skills and become engineers who will shape the engineering profession and society in general. The impact of the course is assessed through student surveys.**

Index Terms – First-year programs, engineering design

INTRODUCTION

Recent research studies have recognized that to remain globally competitive and retain economic leadership, our nation must focus on development in science and engineering to optimize the knowledge-based resources, for job creation and maintaining a high standard of living [1]-[2]. However, as the number of college applications and enrollment of engineering students have dramatically increased in recent years, the overwhelming majority of these students are not exposed to engineering in K-12. Many high school curricula offer few or no hands-on projects and activities that poorly engage students in the field of science and engineering [3].

Furthermore, many of our nation's engineering and computer science programs have not modified their curricula to engage and retain the students. The entering students often are not exposed to any "hands on" experience featuring design, fabrication and testing a technological device until the junior or senior year. Many student experience a discrepancy between the theory-based lectures and practical application of knowledge [4]. This disconnect is often cited by industry who hire engineering students as interns or permanent employees. Additionally, they have limited contact with engineering faculty in their first year as the freshman year comprises primarily general education courses in the Physical Sciences, Humanities, etc. This is a serious weakness in our curriculum that leads to a lack of motivation, discouragement and ultimately matriculation out of engineering. Of particular concern are women and underrepresented minorities who in general have higher matriculation rates out of engineering [5]. In order to combat this problem an integrative and interdisciplinary first-year engineering program providing students with a firm foundation and initial understanding of the engineering profession and its principles has been developed

We present a two-quarter first-year engineering course, Introduction to Engineering, developed and piloted in 2012 to provide students an understanding of both the engineering disciplines and design process. The concepts of product development, project management, technical communication and teamwork are also integrated and introduced in the course simulating "real-world" scenarios to better prepare our students for career paths in industry.

PILOT COURSE

I. Program Preparation and Project Modification

To better understand the structure and possible challenges of formulating and implementing a first-year engineering program, we have visited established several national first-year engineering programs including Purdue University, University of Michigan, The Ohio State University and University of Maryland. After analyzing the distinctive features of each first-year program respectively, we adopted the following practices common to the established programs: engineering design focused, team-based learning, and integration of technical communication. One interesting feature is that all four programs have used undergraduate students as assistants to aid the graduate student or the faculty directly. We were informed that the first-year students would relate more to their peers who were closer to their own age. Therefore, we have also recruited several junior engineering students to assist the program. We chose the autonomous hovercraft developed by University of Maryland (UMD), College Park as the design project for the first freshmen engineering pilot course. The autonomous hovercraft project was highly interdisciplinary in nature and the course content focused not only on the engineering design process, but also on product development. We modified the original one-semester autonomous hovercraft task completed at UMD into two separate projects – remote control (RC) hovercraft and autonomous hovercraft in the Fall quarter and the Winter quarter respectively.

II. Program Formation and Implementation

The Fall quarter pilot course consisted of two one-hour lectures and one three-hour lab per week with technical lectures covering fluid mechanics, basic circuitry, and related foundational topics to complete the remote control hovercraft. Also, due to the large number of students as undeclared engineering majors in the pilot course, faculty representative from each engineering department provided an overview of the individual major and the ongoing research within the department. We believe it was beneficial for students with declared majors as well to acquire a basic understanding of other engineering disciplines, because many emerging fields, such as energy, nanotechnology, etc. are highly multidisciplinary.

Six lab sessions co-taught by TAs and technical staff, were offered with 18-20 students each session and four to six students per team/project. A budget of $250 was given per team to build the RC hovercraft while we supplied all components. The students were trained with necessary fabrication skills such as using hand tools, basic machining, woodwork, and basic electronics during four lab sessions. Students learned Solidworks as the computer-aided design (CAD) software during lab sessions to submit initial and final designs of the hovercrafts. After the initial fabrication training, students were given five weeks to design, build and test the remote control hovercraft. As shown in Figure 1, a final competition based on traversing the hovercraft through a predetermined course in minimum time was held outdoors

FIGURE 1
LEFT: REMOTE CONTROL HOVERCRAFT COMPETITION AT THE END OF FALL QUARTER. Right: AUTONOMOUS HOVERCRAFT COMPETITION AT THE END OF WINTER QUARTER

With a total enrollment of 68 students, the Winter quarter consisted of one one-hour lecture and one three-hour lab per week with lecture tropics on basic C programming, electronics, sensors and controls. Arduino microcontrollers were introduced in lab sessions to enable automation. Students were given the opportunity to regroup, and redesign-build-test a new hovercraft based on their learnings from Fall quarter. A final design report was required from each student team to record the project progress. A final competition was also held with the autonomous hovercrafts tracking a black line on white surfaces as shown in Figure 1.

Furthermore, lectures on product development, project management, engineering ethics and technical presentations were delivered to assist the students in professional development. We also utilized our the advantage of the more than 1200 engineering based companies that have a significant presence in Southern California We invited founders, vice presidents and senior engineers as guest speakers and organized a field trip for students to visit a local design company. The course provided a great opportunity for students to interact with companies and gain a different perspective of engineering through our industry leaders.

COURSE OUTCOMES AND STUDENT FEEDBACK

Throughout the two quarters, we expected the following student outcomes from the pilot course that the students will gain a basic understanding of the following:

- **Engineering design process:** design, build and test
- **Different engineering disciplines**
- **Experience multi-disciplinary project and team-based learning**
- **Technical communication skills:** written design report and oral presentations

We were able to integrate all of the above objectives into our pilot course. Assessment of the class was obtained through student surveys at the end of the each quarter. We asked the students to rate the different aspects of the course effectiveness using a scale of 1 to 5, where 1 is “low”, 2 is “somewhat”, 3 is “adequate”, 4 is “moderate” and 5 is “very high”. 100 students and 66 students participated in the Fall 2012 and Winter quarter 2013 survey respectively. As shown in Figure 2, the average score of course organization and format, course effectiveness in increasing fabrication skills, effectiveness of lecture notes/syllabus/supplies materials, and overall rating were plotted using the scale described above. Error bars were calculated based on standard deviation of the collected data. The error bars indicated a relatively large range of score rating on each course aspect. However, the data exhibited genuine improvements of student experience for Winter Quarter relative to Fall quarter in the average score and also the standard deviation of course effectiveness in increasing fabrication skills, and course overall rating.

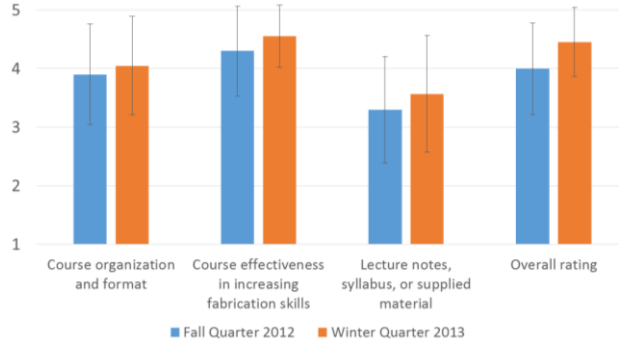
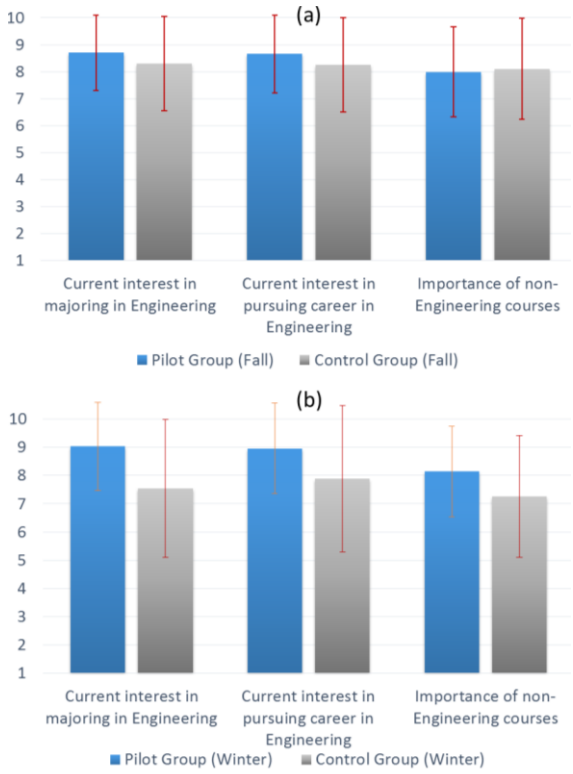


FIGURE 2
COURSE EVALUATION COMPARISON BETWEEN FALL AND WINTER QUARTER OF THE PILOT COURSE. IMPROVEMENT WAS OBSERVED FROM STUDENT SURVEYS CONDUCTED AT THE END OF EACH QUARTER.



SURVEY EVALUATION OF TWO STUDENT GROUPS: STUDENTS IN THE PILOT COURSE AND THE STUDENTS WHO DID NOT TAKEN THE PILOT COURSE. SURVEYS WERE CONDUCTED IN THE BEGINNING OF FALL QUARTER (A) AND AT THE END OF WINTER QUARTER (B).

To further assess the impact of the course on students, a call of survey was sent out via email to the freshmen class. We solicited a cohort of 72 first-year engineering students (control group) who had not enrolled in the pilot course. The same survey was also given to 72 students enrolled in the pilot course (pilot group). The students were asked with the following questions at the beginning of Fall quarter:

1. Rank their current interest in majoring in Engineering on a scale of 1-10 where 1 = "Not interested at all" and 10 = "Extremely interested."
2. Rank their current interest in pursuing a career in Engineering on a scale of 1-10 where 1 = Not interested at all and 10 = Extremely Interested.
3. On a scale of 1-10 where 1 = "Not important at all" and 10 = "Extremely Important," how important do they consider the non-Engineering courses (biology, physics, math, etc.) to current academic and career goals?

Figure 3a shows the average score on a scale of 1 to 10 from student responses, which the average and standard deviation (indicated by error bar) were similar for both groups. However, when the same survey was conducted again at the end of the Winter quarter, we only received 35 responses from the control group while 66 students from the pilot group participated. Furthermore, with the same questions asked, the difference between the average ratings enlarged with an increase for the pilot group and a decrease for control group as shown in Figure 3b, demonstrating the initial positive impact of the pilot course. The standard deviation also enlarged among the control group indicating students were less interested in engineering.

CONCLUSION AND FUTURE WORK

We report on a two-quarter first-year engineering course, developed and piloted successfully in 2012 to provide students an understanding of both the engineering disciplines and design process. Remote control and autonomous hovercraft projects were completed by first-year students in teams in Fall and Winter quarter respectively. Impact of the course will be continuously assessed through surveys, student retention, and grades in physics, math, and other engineering courses.

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