Assessing the impact of a first-year experiential learning course on women and underrepresented students

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***Abstract* - This work in progress describes the implementation of a two-quarter first-year engineering program and the course impact on women and underrepresented students. The first-year engineering course focused on team-based experiential learning and taught the concept of engineering design through two hands-on projects, where students acquired engineering skills in CAD, basic machining, fabrication, circuitry and microprocessor programming. In addition, the course provided instructions on project management and teamwork, and opportunities to interact with faculty and industry speakers from different engineering disciplines. A control group was solicited among students who were not enrolled in the course during their first-year. Self-assessed student surveys were administered to both groups evaluating their motivation in engineering at the beginning of Fall quarter, and at the end of Winter quarter during their freshmen and sophomore year respectively. Survey results were compared between the cohort enrolled in the first-year course and the control group, among women and underrepresented students, to examine the impact of the course on student motivation.**

Index Terms – Experiential Learning, Underrepresented Students, First-year Engineering, Teamwork

INTRODUCTION

The lack of applied project-based experiences among lower division courses causes many students to lose interest and leave engineering during the first year, without understanding the importance of rigorous training in math and physical sciences. Many programs implemented innovative first-year courses to enhance engineering curriculum and increase student retention [1]. However, national data has demonstrated the lack of pipeline in STEM field for female and underrepresented (URM) students at each degree level [2].

Retention of female and underrepresented students has been a challenge in engineering and are effected by various factors, for example, the impact of self-efficacy [3]-[4], persistence[5], etc. To improve success of female and URM students in engineering, many national programs have developed and implemented living-learning communities to enhance persistence [5].

We implemented a two-quarter first-year experiential learning class, which focused on design-build-test of a hands-on project. To provide better community support for female and URM students, team-based learning was implemented. Two groups of students who took the course (Pilot Group) and who did not enroll in the course (Control Group) were recruited to participate in self-assessed surveys. Results in student motivation in engineering were compared between the two groups to evaluate the differences among women and URM students.

COURSE INFORMATION

The first-year engineering course consisted of two lectures and a two-hour lab per week in Fall, and one lecture and a two-hour lab per week in Winter quarter. The project was to design, build and test a RC controlled quadcopter during Fall, and an autonomous payload delivery quadcopter during Winter. The course lectures covered a variety of topics including technical knowledge related to quadcopter design, introduction to different engineering disciplines, and project management. To engage student interactions with industry leadership, start-up founders and industry guest speakers were invited to deliver presentations on various topics such as professional development, current research trends, product development, etc. In addition, lectures on entrepreneurship were integrated during Winter quarter to allow students to develop a business plan related to the quadcopter project.

Lab sessions were designed for students to apply the technical contents to their project and were co-instructed by graduate teaching assistants and laboratory staff. Students were trained on SolidWorks (as CAD software), basic machining, electrical fabrication and programming microcontrollers. The option of using 3D printing and/or laser cutting was offered as an alternative fabrication approach. Students were required to submit a short team report on a weekly basis to describe their progress and milestones to keep the project on track. Through a focus group interview with the first cohort of freshmen students

from 2012-2013, several female students, who were the only woman in an all-male team, reported that they had been assigned with secretarial tasks or experienced discrimination from their male team members. Therefore, starting the second year of course implementation, no single female or URM student was placed in a team alone during Fall. At least two female students or two URM students were teamed in the same group based on survey results from CATME (https://catme.org) developed by Purdue University.

The first-year course was currently approved as a technical elective for most engineering majors in the school. Freshmen students were enrolled on a self-selecting basis during the summer before their first quarter at the university. For the 2014-2015 cohort, which this study was performed, we successfully enrolled 223 students in Fall of 2014, and 158 students in Winter of 2015 across all engineering disciplines. Through surveys, majority of students stated schedule conflict or course overload was the main reason that they could not return during Winter quarter. However, 88% of the students recommended the course to incoming freshmen peers, indicating their favorite component of the course being the hands-on learning. Figure 1 showed the quadcopters made in teams by students and the delivery of the payload via distance and color recognition.

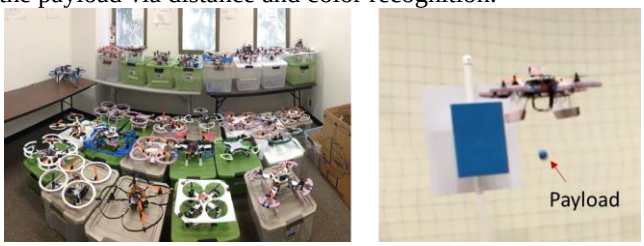

FIGURE 1
LEFT: QUADCOPTER MADE BY STUDENTS IN WINTER QUARTER ACCORDING TO GIVEN DESIGN SPECIFICATIONS.
RIGHT: AUTONOMOUS DELIVERY OF PAYLOAD FROM QUADCOPTER BASED ON DISTANCE AND COLOR RECOGNITION USING AN ULTRASONIC SENSOR AND A CAMERA RESPECTIVELY.

METHODOLOGY

Two groups were assessed in this study: students who enrolled in the course (Pilot) and students who were not enrolled (Control). A self-assessed survey was administered to both groups at the beginning of Fall Quarter (F14), at the end of Winter Quarter (W15) and the end of Winter Quarter in the subsequent year (W16). The following questions were listed as part of the survey:

- Rank current interest in majoring in Engineering on a scale of 1-10 where 1 = "Not interested at all" and 10 = "Extremely interested."
- Rank current interest in pursuing a career in Engineering on a scale of 1-10 where 1 = Not interested at all and 10 = Extremely Interested.
- 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?

Results collected from female and URM students were evaluated separately. For statistical analysis, differences among women students between pilot and control were tested for Fall of 2014 (F14), Winter of 2015 (W15) and Winter of 2016 (W16) by the Student's *t*-test. Similarly, differences among URM students between pilot and control groups were tested across three terms. Differences were considered significant if $p < 0.05$. Sample sizes are relatively small because students participated in surveys on a voluntary basis.

RESULTS AND DISCUSSION

I. Female Students

Figure 2 shows the bar representation of student responses of the mean on a scale of 1 to 10 with error bars indicating standard deviation. Female student responses are indicated in blue for the pilot group, and in red for the control group, across terms. F14, W15 and W16 represent Fall of 2014, Winter of 2015 and Winter of 2016, respectively. Notably, the largest difference occurred at the end of Winter Quarter (W15) where the first-year course concluded. For the pilot group, the mean values of students' interest in engineering, interest in pursuing a career in engineering and the importance of non-engineering courses all increased, when mean values of the control group decreased. As also indicated by Table 1, the W15 differences between the two groups were significant for all three survey questions ($p<0.05$). Therefore, female students in the pilot group demonstrated a higher interest in engineering and pursuing a career in engineering. Furthermore, the pilot group also expressed a better understanding of the importance of non-engineering courses. However, at the end of W16, the mean values of the pilot group decreased significantly in comparison to W15 as illustrated by Figure 2. Although the pilot group maintained a slight higher mean comparing to the control group, the significance in differences diminished as shown in Table 1, which could be attributed to the lack of hands-on courses during sophomore year for the pilot group.

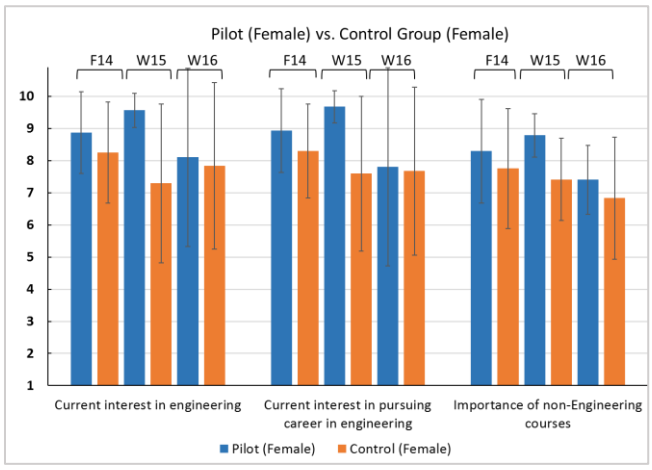

FIGURE 2
SURVEY EVALUATION ON STUDENT MOTIVATION OF WOMEN STUDENTS BETWEEN PILOT AND CONTROL GROUP. RESULTS ARE COMPARED ACROSS TERMS: F14, W15 AND W16.

Assessment Questions	Term	Mean ± Standard Deviation, N		p-value
		Pilot	Control	
Current interest in majoring in engineering	Fall, 2014 (F14)	8.86 ± 1.27, 28	8.25 ± 1.57, 24	0.13
	Winter, 2015 (W15)	9.56 ± 0.53, 9	7.29 ± 2.47, 17	**0.013**
	Winter, 2016 (W16)	8.10 ± 2.77, 10	7.83 ± 2.59, 12	0.82
Current interest in pursuing a career in engineering	Fall, 2014 (F14)	8.93 ± 1.30, 28	8.29 ± 1.46, 24	0.10
	Winter, 2015 (W15)	9.67 ± 0.50, 9	7.59 ± 2.40, 17	**0.018**
	Winter, 2016 (W16)	7.80 ± 3.08, 10	7.67 ± 2.61, 12	0.91
Importance of non-engineering classes	Fall, 2014 (F14)	8.29 ± 1.61, 28	7.75 ± 1.87, 24	0.27
	Winter, 2015 (W15)	8.78 ± 0.67, 9	7.41 ± 1.28, 17	**0.0065**
	Winter, 2016 (W16)	7.40 ± 1.07, 10	6.83 ± 1.90, 12	0.41

TABLE 1

NUMERICAL COMPARISON OF FEMALE STUDENT MOTIVATION OF PILOT AND CONTROL GROUP ACROSS TERMS. MEAN, STANDARD DEVIATION AND P-VALUE ARE CALCULATED. N REPRESENTS THE SAMPLE SIZE.

II. URM Students

Similarly, URM student responses are represented as shown in Figure 3 to illustrate the trend between the pilot group and the control group, across three terms. Mean values of the pilot group are indicated by bars in green, and in yellow for the control group, with standard deviation as error bars. Numerical values are listed in Table 2 as a comparison with p-value provided to indicate statistical differences. A significant difference was found between the URM cohorts that the control group started in engineering with a stronger interest in engineering at the beginning of F14. However, at the end of W15 (the end of first-year course), the pilot group exhibited a significant increase in motivation comparing to the control group in student interest in engineering and their current interest in pursuing a career in engineering ($p<0.05$). Similar to the female students, the differences in student motivation diminished at the end of W16, which could be attributed to the same reason that experiential learning did not exist during the second year.

In contrast to female students, the URM student responses did not exhibit significant differences between the pilot and control group, regarding how important students had considered non-engineering courses to their learnings at the end of W15. As shown in Figure 3, both groups exhibited consistent decrease across F14, W15 and W16. Further studies are needed to examine the cause.

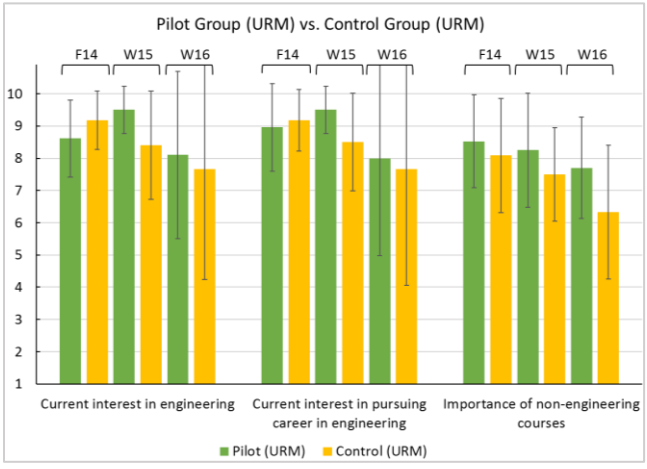

FIGURE 3

SURVEY EVALUATION OF URM STUDENT MOTIVATION BETWEEN PILOT AND CONTROL GROUP. RESULTS ARE COMPARED ACROSS TERMS: F14, W15 AND W16.

Assessment Questions	Term	Mean ± Standard Deviation, N		p-value
		Pilot	Control	
Current interest in majoring in engineering	Fall, 2014 (F14)	8.61 ± 1.20, 23	9.18 ± 0.91, 22	**0.08**
	Winter, 2015 (W15)	9.50 ± 0.73, 16	8.42 ± 1.68, 12	**0.029**
	Winter, 2016 (W16)	8.10 ± 2.60, 10	7.67 ± 3.44, 6	0.78
Current interest in pursuing a career in engineering	Fall, 2014 (F14)	8.96 ± 1.36, 23	9.18 ± 0.96, 22	0.53
	Winter, 2015 (W15)	9.50 ± 0.73, 16	8.50 ± 1.51, 12	**0.028**
	Winter, 2016 (W16)	8.00 ± 3.02, 10	7.67 ± 3.61, 6	0.85
Importance of non-engineering classes	Fall, 2014 (F14)	8.52 ± 1.44, 23	8.09 ± 1.77, 22	0.37
	Winter, 2015 (W15)	8.25 ± 1.77, 16	7.50 ± 1.45, 12	0.24
	Winter, 2016 (W16)	7.70 ± 1.57, 10	6.33 ± 2.07, 6	0.16

TABLE 2

NUMERICAL COMPARISON OF URM STUDENT MOTIVATION OF PILOT AND CONTROL GROUP ACROSS TERMS. MEAN, STANDARD DEVIATION AND P-VALUE ARE CALCULATED. N REPRESENTS THE SAMPLE SIZE.

CONCLUSION AND FUTURE WORK

This work in progress paper reports on a two-quarter first-year engineering course implemented during 2014-2015. The course focused on experiential learning by allowing students to design, build and test RC and autonomous delivery quadcopters in teams. The course successfully increased student motivation in pursuing engineering for both URM and female students. The female students who were enrolled in the first-year course also exhibited a better understanding of the importance of non-engineering courses. Results demonstrated that to retain student motivation for URM and female students, experiential learning courses in the subsequent years should be considered. For future work, teamwork, student efficacy and student grades in other engineering courses will be continuously assessed to evaluate the course impact on female and URM students.

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