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Developing STEM-preneur through Engineering Innovation Hands-on Projects

Introduction: Research in engineering education over the past 15 years has shown that the interest in pursuing undergraduate degrees in engineering has declined amongst graduating high school students. It also revealed that only half of the students entering U.S. universities as engineering majors actually complete all degree requirements [1]. The engineering graduation rate is even lower for Texas Higher Education institutions. It has also been noted that many students made their decision to leave an engineering major within the first two years, the period during which they are taking engineering prerequisites and before taking any (or many) engineering courses [2]. One of the potential reasons for this situation is that students in their first two years are given little exposure to the many possibilities that an engineering career can offer, while they are taking math and science courses taught outside of engineering departments. It suggests that few students-even those who have had some prior exposure to engineering-know what engineers do, and this affects their commitment to the engineering major [2]. As a result, programs that expose students to engineering experiences and/or projects early in their college studies might have a greater chance of both enticing students to persist and interesting them in specific sub-fields of engineering.

In the paper, the authors will present a project that is motivated to explore how to improve STEM learning outcomes and retention of engineering majors by introducing hand-on projects, which combining STEM learning with entrepreneurship, into the freshman engineering curriculum (MEEN 1310-Computer Based Graphics and Design I and MEEN 1320 Fundamental of Numerical Method). This project is supported by HP Catalyst Initiative to develop a new STEM-preneur learning environment through engineering innovation hands-on projects by using HP's technology. The new STEM-preneur learning modules will help students understand STEM concepts and improve entrepreneurial thinking through hands-on experiences. This curriculum innovation will also give the students the opportunities to work on the real life hands-on projects at an Innovation Lab that serves as a connection between college and local industries. A specific evaluation plan is designed to address progress, achievement, and impact of the project objectives and overall goals.

Literature Review: A large portion of the engineering education research focuses on factors used to predict the likelihood that a student will successfully complete an undergraduate degree in engineering. These factors include: a student's prior academic attainments, level of commitment, personal motivation, and level of enjoyment and satisfaction. The literature cites a number of factors, often thought to be isolate and independent, for why students leave engineering. A student's reasons for choosing to pursue an engineering degree appear to be related to their persistence. Specifically, choosing to major because one identifies with engineering and the activities that engineers engage in is positively associated with commitment to majoring in engineering. Those students with a strong connection between their identification with engineering and their perception of the activities that engineers engage in are more likely to show unwavering commitment to engineering. In contrast, students with a weak connection between their engineering-related identity and the activities in which engineers engage showed continual renegotiation of their commitment to engineering. Many students' decisions about majoring in engineering are malleable and that this flexibility even continues up to the point of choosing a job (or other opportunity) after graduation [2].

Research into the undergraduate preparation of engineers has largely been focused on how to retain students in the major, and several studies over the years have identified reasons that students migrate into other majors or interventions that might increase persistence [3]. Performance in calculus courses, the most commonly cited is believed to be the largest obstacle for first-year students in engineering programs. The design of most engineering curricula expects students to be calculus-ready when they arrive at college. Many are not. Thus, when students fail or withdraw from Calculus I, it greatly affects their progress in engineering programs more so than any other courses [4]. Receiving grades in introductory courses that were far lower than their high school grades caused a shock to students' ego and resulted in switching decisions. Students' attitudes also play a role in their persistence in mathematics and subsequent persistence in engineering. We also note that many students make the decision to leave an engineering major within the first two years, the period during which they are taking engineering prerequisites and before taking any (or many) engineering courses [2]. One potential factor in this situation is that students are given little exposure to the many possibilities that an engineering career can offer in the first two years, while they are taking math and science courses taught outside of engineering departments. It suggests that few students-even those who have had some prior exposure to engineering-know what engineers do, and this affects their commitment to the major [2]. As a result, programs that expose students to engineering experiences and/or projects early might have a greater chance of both enticing students to persist and interesting them in specific sub-fields of engineering.

Project Description: The project is motivated by the following problem: How to increase the retention rate of engineering majors by increasing engineering related knowledge and projects into their first two years curriculum courses.

Retention of students in colleges of engineering is an issue of current concern, since engineering graduates provide a high percentage of tomorrow's technical workforce. Some argue that retention is so important it should be used as a college outcomes assessment parameter and that it be considered a measure of our abilities as faculty and professional engineers to design programs of study that meet market and customer expectations [5]. Historically, engineering enrollment has focused on new student recruitment, but recently much more attention has been directed toward the issue of student retention. Although recruitment remains fundamental in today's educational environment, student retention is becoming increasingly important. Studies have shown that it is much more expensive to recruit a new student than it is to keep a current one. In addition, if students are not successful in completing their degrees, there can be serious institutional implications. For example, student attrition raises questions about the institutional priorities, particularly those of teaching and student development. In recent years, retention rates have been cited as one of the critical measures of institutional effectiveness. Educational stakeholders (e.g., taxpayers, legislatures, parents) have assumed greater oversight authority and have demanded more accountability from public institutions. Student retention rates are rapidly becoming a popular measure upon which institutional comparisons are made and their effectiveness judged. It is important that engineering colleges develop a retention strategy for their programs. Nationwide, less than half the freshman who start in engineering graduate in engineering, and at least half of this attrition occurs during the freshman year. Clearly, the freshman year is critical for both academic success and retention of engineering students [6]. By measuring changes in student attitude over the course of the freshman year, we can develop better methods to evaluate engineering education programs. Retention in engineering has been studied from several perspectives: gender, race, geographical backgrounds, personality differences, as well as intellectual factors. Education is an aggregate of both cognitive (content knowledge and technical skills) and affective (attitudes) processes. Engineering students begin their college education with a set of attitudes about engineering and their abilities to succeed. These initial attitudes and their changes during the freshman year affect students' motivation, performance, and ultimately retention in an engineering program. There is strong evidence that among all factors studied, attitudes are the most correlated with retention. To introduce more engineering related contents and projects into the first two year courses can provide the students more information about what engineering is, and provide positive effects on students' attitudes of engineering.

Engineering faculty, from the leading institution of the project Texas A&M University - Kingsville, leads the curriculum innovation by developing the learning modules and proper hands-on projects. Faculty from the participating institution, Del Mar College, will select the proper learning modules and projects to be adopted in their curriculum. Many Del Mar students have transferred to TAMU-Kingsville to get their BS degrees after they graduate from Del Mar with associate degrees. The shared curriculum and projects will enrich the first two year of studies and will enable them smoothly transfer to four year college and successfully complete their undergraduate studies.

Some of the hands-on projects will also be used in high school summer camps to expose high school students to STEM-preneur concepts and hands-on experiences. TAMU-Kingsville has organized a total of four high school summer camps in the past two years with about 150 students participating per year. These activities will be continued in 2012 and in the coming years. Two faculty members from the project team have been highly involved and have served as faculty advisors for the summer camps.

Student Entrepreneurship Hands-on Project Design: Students will required to do a semester-long group project focuses on integrating Innovative Engineering Project with Entrepreneurial Thinking. Students will choose a topic related to engineering innovation, and apply the knowledge learned in MEEN 1310 and entrepreneurial thinking in the project. Each group has five to six students. Three presentations and reports are required. The first presentation and report is focused on topic selection. Students have to justify the rational of the selected topic and how they are going to use both the entrepreneurial thinking and engineering knowledge in the project. The second presentation and the report is the progress report and the last one is the final complete report.

Guidelines, references and the sample project topics are given to the students. Students are encouraged to meet with the professor during the lab hours to discuss the progress and questions of their projects. Engineering thinking includes (not limited to) existing product modification/redesign and new product design. The team needs to 1) justify their selection by finding the current design disadvantages or current market/customer requirements, 2) modify the current design and present the new design using engineering drawings, 3) justify their new design using entrepreneurial thinking. Entrepreneurial thinking includes (not limited to) brain storming, teamwork, economic analysis, payback period analysis, market analysis, and decision making. Results (or part of the results) should be able to be presented using engineering drawings, including freehand lettering/sketching, orthographic projection, and etc. So far, students have done the first phase of the project. Some interesting topics they have selected include: portable podium design, design of a bottle opener that can work for twisting off caps and popping off caps, improving design of vegetable slicer, and redesign school bus seats.

Peer reviewing will be used to evaluate their projects. Each presentation will be evaluated by both instructor and peer groups. By the end of the semester, each student will submit a self-evaluation and s/he will also be evaluated her/his teammates.

Evaluation Plan: The evaluation plan, designed to address progress, achievement, and impact of the project objectives and overall goals, will be both formative and summative to measure the successful project development, implementation, and dissemination of outcomes. Evaluation will consist of the quantitative and qualitative assessment of expected outcomes and will include detailed and focused descriptive information about the interventions and methods employed to achieve each objective, particularly to changes in the implementation strategies from one year to the next.

The internal evaluation will be conducted and guided by the PI and she will work with Co-PIs and other participates to collect data to evaluate the following **project outcomes**:

Outcome 1: Engineering hands-on projects combining STEM concepts and knowledge with entrepreneurial critical thinking are introduced to Mechanical Engineering freshmen courses. **Outcome 2**: Students' learning outcomes from the pilot courses are improved, and students' engagement and retention in engineering major are increased.

Outcome 3: STEM-preneur trainees are better marketable and employable because of their training in both STEM and entrepreneurial thinking by using HP technology.

Outcome 4: Engineering hand-on projects are introduced to high school students to prepare STEM-preneur pathway.

Following sample questions will be used to evaluate the outcomes:

1. Students and other participants' quality (related to outcomes 1, 2):

1.1 Have the STEM-preneur consortium been introduced to students and other participants?

1.2 Have participants worked on the roles in the project as they committed?

1.3Have the courses offered by faculty satisfied learning outcomes and student evaluation results?

2. Curriculum innovation quality (related to outcomes 1, 2, 3):

2.1 What are the educational activities trainees have attended, including courses taken, hands-on projects, seminars, internships, etc.?

2.2 Have trainees satisfactorily accomplished each training activity?

2.3 How well do trainees' retention in engineering major and grow in professional skills, knowledge, and personal characters satisfy future workforce needs?

3. Work force needs satisfaction (related to outcomes 3, 4):

3.1 How well have graduated trainees satisfied Texas, national and international workforce needs on STEM-preneur?

3.2 What are the trainees' advantages comparing to their competitors in job hunting?

3.3 How successful are the trainees' careers after this program?

3.4 Has the program been updated and adjusted to satisfy changing workforce needs?

3.5 Has the program completed necessary outreach activities to local high schools?

Table 1: Evaluation and Assessment Activities

Evaluation Task	**Yearly Timeline**	**Related Evaluation Questions**
Recruitment and retention data collection	Fall, Spring, Summer	1.1, 2.1, 2.2, 2.3
Trainees' training activities participation data collection	Fall, Spring, Summer	1.1, 1.3, 2.1, 2.2, 2.3
ABET annual self-evaluation and report	Spring	1.1, 1.2, 1.3, 2.1, 2.2, 2.3
Course evaluation	Fall, Spring, Summer	2.1, 2.2, 2.3
Trainee interview	Fall	1.1, 1.2, 2.1, 2.2, 2.3

Trainee on-line survey	Spring	1.2, 3.1, 3.2 , 3.3
Employer and Alumni survey	Summer	3.1, 3.2, 3.3, 3.4
High school teachers and students survey	Fall, Spring	3.5
External advisory board meeting and teleconference	Fall, Spring	1.2, 2.1, 3.1, 3.2, 3.3
Follow-up data collection on graduated trainees	Spring	3.1, 3.2, 3.3, 3.4
STEM-preneur pathway data collection	Summer	2.1, 3.5

Support from Industry Sponsor: The HP equipment has been set up in Javelina Innovation Laboratory and will be used by the students from MEEN 1310 and MEEN 1320 in-class and after-class on their hands-on projects. Currently, each section of MEEN 1310 and MEEN 1320 has less than 50 students. The lecture sections of both courses are taught in a regular classroom without student computers. Although the instructors are using projector and presentations to show some real-world engineering examples in the classes, the students cannot try those examples in the classrooms. The equipment funded by HP allow each student to have his/her own computer in the class and will be able to access the innovative engineering related class materials and projects. The Mini Notebook PCs will also allow students to perform data collection and preliminary results analysis on-site when they work out of doors or have a field trip to companies. These portable devices can be linked to the server so that data collected and preliminary results analyzed can be easily stored on the server for future processing and detail analysis. Two servers will be set up using the HP Proliant Servers and hard disks. One server will be used for internal data storage and communication, while the second one will be used for external data exchange that will allow access by the students, faculty in Del Mar College, and industrial companies.

The HP Elitebook Tablet PCs together with HP Virtual Room will be used to set up a net meeting conference room. It will allow the students and faculty in Javelina Innovation Center to have meetings with participating company managers or faculty in Del Mar College, to discuss the detail requirements and progresses of the engineering projects without having to travel to each location. One more HP Virtual Room will be used in the computer laboratory, so that the students in Javelina Innovation Center can have a real-time discussion with the students in Del Mar College. The HP Elitebook Tablet PCs will also allow the instructors to create innovative interactive class materials that will increase the attraction of STEM related topics. We hope the engineering related interactive class materials and real life projects can raise the awareness of engineering students and let them continue with their engineering degrees. All the new class materials and projects will be stored on servers and accessed 24X7 by external companies and universities.

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