Innovative STEM-Preneur Learning Modules for Freshman Robotic Engineering Class

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1. Introduction

Research in engineering education over the past 15 years has shown that US undergraduate engineering student enrollment in decline while the demand for qualified engineering graduates is expected to increase[1]. The U.S. Bureau of Labor Statistics (BLS) predicts a 22% growth in jobs for fields related to Science, Technology, Engineering, and Mathematics (STEM) between 2004 and 2014 (U. S. Department of Labor, 2005)[2]. It revealed that fewer than 40 % of students who enter college intending to major in a STEM field complete college with a STEM degree today[3]. The engineering graduation rate is even lower for Texas Higher Education institutions[4]. Research by ACT indicates that fewer than one in five 12th graders have both high interest in STEM and high proficiency in mathematics-precursors to success in STEM undergraduate program[2]. 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[5]. One of the potential reasons for the current crisis 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. Encouraging our youth to pursue careers in the STEM fields has been viewed as crucial in recent years, to meeting humanity's needs, both nationally and globally[6]. 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[5]. Changes in the economy and workforce needs have led many engineering schools to consider offering entrepreneurship education to their students. Connecting the fields of engineering with business and entrepreneurship in higher education has yielded a wide range of innovative and useful outcomes, products, and organizations. A previous study explored engineering students' levels of interest and involvement in entrepreneurship, their perceptions of its impact on self-efficacy, and the characteristics of students who participate[7]. Students who had taken one or more entrepreneurship courses showed significantly higher levels of entrepreneurial self-efficacy on a number of measures. The Engineering Entrepreneurs Program at North Carolina State University, which undergraduate students participate in design teams formed around technology start-up company themes, was primarily to improve the confidence and retention of engineering students[8]. Multiple assessment approaches including surveys, focus groups, interviews, longitudinal assessment of retention and academic performance, and anecdotal evidence triangulate on the success of this program at meeting its primary objectives and others. Particularly, the longitudinal study revealed that program participants had higher engineering retention rates (70 percent vs. 51 percent) and GPAs (3.08 vs. 2.83) than a matched set of non-participants.

As a result, programs that expose students to engineering experiences and/or hands-on projects with entrepreneurs thinking early might have a greater chance of both enticing students to persist and interesting them in specific sub-fields of engineering.

2. Project Background

From Pre-K to Graduate programs, each level of education has its own values and expected outcomes. The teaching methods and materials used at each level of education are chosen to fulfill its own purpose. However, there should have some specific projects or concepts that may be used in different levels of education without altering the central questions. In this external founded project, the focus is to develop STEM related course projects with entrepreneurial thinking concept that can be used across different education levels. Entrepreneurial thinking is always attractive to young generations. Different levels of math varying from mathematical modeling to calculating cost of 3 gram aluminum can be integrated into entrepreneurial projects.

The authors choose one mechanical engineering freshman course at Texas A&M University-Kingsville (TAMUK) to test the entrepreneurial concepts first, and implement them in a community college course at Del Mar College (DMC). The two institutions both locate in Corpus Christi, TX, where almost no local internship opportunity available for STEM students. Few engineering students get the opportunity to experience a true work environment before being thrust into the workforce after graduation. How to prepare the STEM students for their future job displacements and career development is another challenge. In the TAMUK freshman course, semester-long design project with different entrepreneurial concepts are introduced into the curriculum, where the concepts include teamwork, brainstorming, market analysis, product economic analysis, payback period analysis, project management, and etc. A promising result was obtained through pre and post student survey, which shows about 30% increase in terms of interest towards STEM. In this paper, the author will focus on the DMC course, i.e. freshman robotic engineering course, in which all students are given the same project with required business activities.

3. Learning Module Design and Implementation

The learning module is used in a freshman level “Robotic Fundamentals” course at DMC. This is a core course for Engineering Technology students and an elective course for Electrical Engineering, Mechanical Engineering and Computer Science disciplines. The course is offered in Spring and Fall semesters and meets twice per week with one hour lecture and two hours laboratory each time. There were eight students including three female attended the course during Fall 2013 semester, with two students from Engineering Technology, two students from Mechanical Engineering, one student from Electrical Engineering and the remaining three students from Computer Science disciplines.

Two or three students are required to form a team to brainstorm, conduct research, design, build, and test a robot using LEGO Mindstorm NXT. The project simulates a real business case. The teams were asked to investigate, design and implement a prototype of a small, inexpensive system that can fulfill the given engineering challenge with the limitation of the budget for materials and labors. The challenge was to design and program a robot to maneuver through a given test area in the shortest time, as shown in Fig. 1. It required the robot to go forward, backward, make turns, sense/avoid objects, sense/response the light, and sense/response the sound. The challenge requires a team to practice following business activities: 1) Project planning; 2) Time management; 3) Cost management including Inventory control and Staff

control, and 4) Marketing analysis and business presentation. Each team was given the same budget and has the same limitation of available working time and staff. The course instructor serves as a supplier, who has different available robot parts with different purchasing price. Each team has to create their own design of robot within the limitation of budget, available time and staff. Each team was also given a detailed timesheet to record their working hours in order to make sure they satisfy the requirements. A team leader is required to be selected, who will serve as project manager of the team to arrange different activities. The students are not only required to create a robot to fulfill the technical challenge, but also to conduct an economic or market analysis for their own robots. The final project grade considers students' performance in both technical and business aspects.

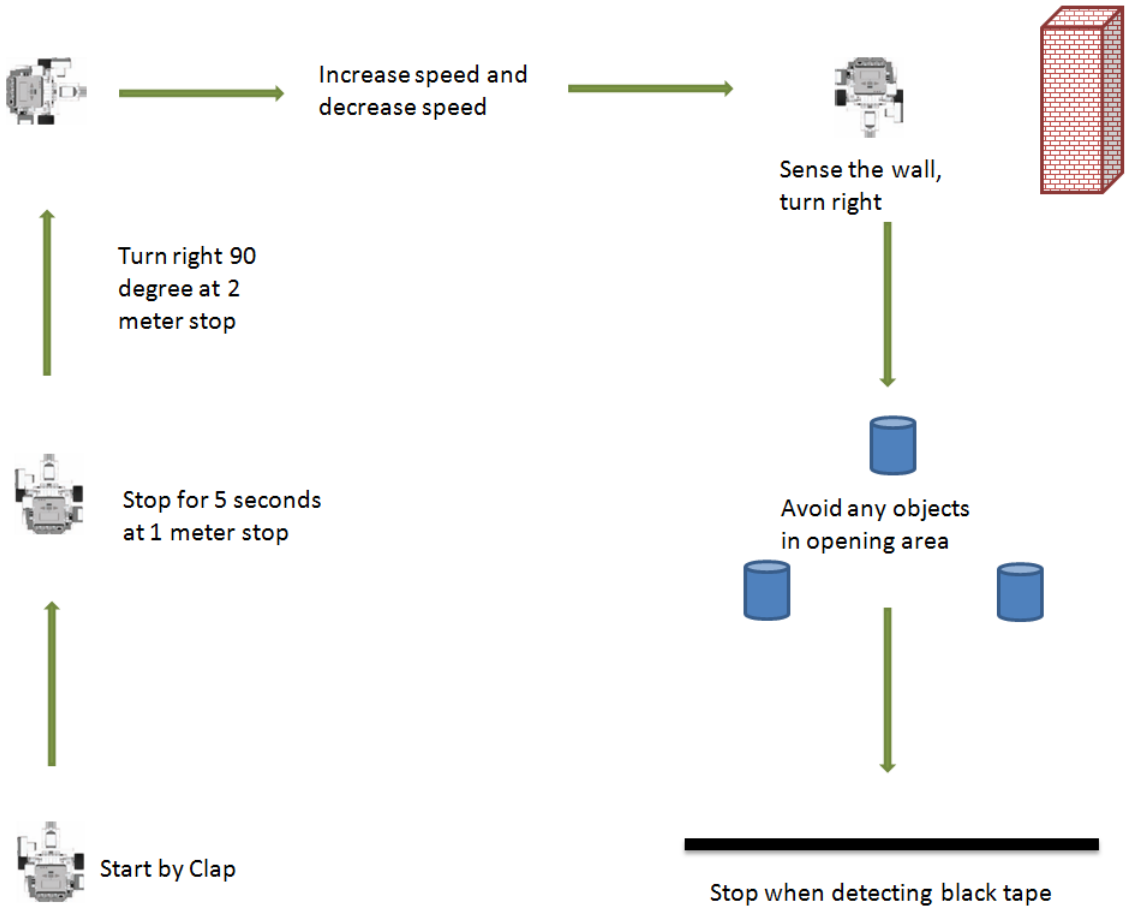

Figure 1. Project Challenge Layout

The implementation of the learning module with six major engineering design steps during the six-week course curriculum is described in Table 1 below with detail weekly lectures, laboratories, entrepreneurial thinking, and deliverables. The learning module integrated the innovative entrepreneurial thinking into a hands-on robotic engineering project. Different with previous curriculum, entrepreneurial concepts are added into the regular lecturers. The course instructor was successfully modified the previous curriculum to get extra hours for the additional entrepreneurial concept lecturers. Due to the limited available teaching hours, several lecturers have to be given during the lab.

Table 1. The Learning Module Curriculum

Week 1: Problem Definition	Lecture	Introduction to the history of robot
		Introduction to project challenges
		Introduction to the engineering design process
	Laboratory	Form teams
		LEGO MindStorm NXT (project hardware)
		LEGO NXT/Robot C (project software)
	Entrepreneurial Thinking	Teamwork
	Deliverables	The problem definition
Week 2: Problem Specification	Lecture	Study controllers, sensors, motors, chassis and other physical structures of robots
		Write an engineering design specification
	Laboratory	Hands-on labs for LEGO
		Requirement analysis
	Entrepreneurial Thinking	Project Planning; Cost analysis; Inventory control
	Deliverables	Request for Proposal(RFP); project timeline
Week-3: Design	Lecture	Programming (flowchart and pseudo code)
		Programming (algorithms)
	Laboratory	Propose solutions
		Build prototype
	Entrepreneurial Thinking	Time Management
	Deliverables	Design specification
Week-4: Evaluation	Lecture	Transition from problem domain to solution domain
	Laboratory	Evaluate solutions
	Entrepreneurial Thinking	Product Comparison Matrix
	Deliverables	Solution evaluation
Week-5: Implementation and Testing	Lecture	Test plan design
	Laboratory	Build and test robots
	Entrepreneurial Thinking	Marketing analysis
	Deliverables	Test report
Week-6: Publication	Lecture	Write an engineering report
	Laboratory	Test robots
	Entrepreneurial Thinking	Sell your product
	Deliverables	Team demo/presentation, project report

4. Learning Module Evaluation

The pre and post surveys were conducted to monitor and evaluate the effectiveness of the learning outcomes through engineering projects which combining the powerful STEM knowledge and innovative entrepreneurial thinking. The pre-survey took place at the beginning of the project and focused on students' interests, understandings and opinions about STEM in their studies as well as their believes of their success with future STEM/Engineering related interdisciplinary study and career. The post-survey was conducted at the end of the project with equivalent items to compare with the pre-survey to quantify the student educational outcomes and the effectiveness of the project experience. A total of eight students participated in the pre-survey and the post-survey. In the pre-survey, six out of eight students either never heard the term of STEM or only head term. The project gave them experience and increase their awareness and interest in STEM fields and careers. The learning module impact on the project students is illustrated by comparing the same questions in both pre- and post-surveys, as shown in Table 2, 3, 4, and 5, where the first numbers and second numbers in parentheses indicate student selections in the pre- and post-surveys, respectively.

Table 2 Indicate how much each of different activities will help students to your understand STEM. And Table 3 indicates students' feeling for different activities which will increase their interest in engineering/STEM fields

Table 2. The comparative results for the pre- and post-surveys

Activity	A Great Deal	A Lot	Somewhat	A Little	Not At All	Not Sure
Class lectures	3(4)	2(3)	3(1)			
Working in teams	6(7)	0(1)	1(0)	1(0)		
STEM projects	4(5)	2(2)	0(1)	1(0)		1(0)
Labs	2(6)	3(1)	1(1)	1(0)		1(0)

Table 3. The comparative results for the pre- and post-surveys

Activity	A Great Deal	A Lot	Somewhat	A Little	Not At All	Not Sure
STEM project	2(2)	3(4)	1(2)	1(0)		1(0)
STEM/Engineering internship	5(3)	3(5)				
STEM/Engineering class in freshman and junior years	3(3)	3(5)	2(0)			
Team working experience	4(4)	3(4)	1(0)			

Table 4 Indicates students' level of agreement with each of the following statements related STEM and Business Thinking. And Table 5 indicates how important students believe different knowledge and skills is to their success with future STEM/Engineering related interdisciplinary study and career.

Table 4. The comparative results for the pre- and post-surveys

Statement	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
Participation in peer reviewing will enhanced my educational experience.	3(2)	3(4)	2(2)		
Working on STEM activities will increase my skills in working across multiple engineering and science disciplines.	3(4)	3(3)	2(1)		
Integrating STEM project in the curriculum of this class will increase my engagement in class activities.	4(3)	3(4)	1(1)		
Integrating the Business Thinking into STEM project in this class will make the class more valuable to me.	2(4)	3(2)	3(2)		
Integrating STEM project in the curriculum of this class will increase my interests and understanding of engineering/STEM.	4(5)	2(3)	1(0)	1(0)	
Integrating the Business Thinking into STEM project in this class will increase my interests and understanding of engineering/STEM.	4(6)	2(1)	2(1)		

Table 5. The comparative results for the pre- and post-surveys

Knowledge and Skills	Very Important	Important	Somewhat Important	Only a Little Important	Not Important At All	Not Sure
Understanding how engineering fields are connected with business thinking	4(5)	2(2)	1(1)			1(0)
Problem solving skills	5(6)	2(2)	1(0)			
Teamwork skills	5(7)	2(1)	1(0)			
Content knowledge in different engineering fields	3(5)	3(1)	1(2)			1(0)
Understanding how engineering fields are connected with each other	4(4)	3(4)	1(0)			

The DMC also has its own official course evaluation at end of each semester. The results of the selected robotic course evaluation are shown in Table 6.

Table 6. Results of official course evaluation conducted by DMC

Question	Course Mean	Department Mean	College Mean
1. The instructor is well organized, prepared, with clear classroom procedures.	4.71	4.51	4.49
2. The instructor displays a personal interest in students and learning.	5.00	4.51	4.50
3. The instructor provided opportunity for group activity and discussion in class.	5.00	4.35	4.38
4. Homework, tests, projects, etc. are turned in a timely manner with useful feedback.	4.29	4.36	4.45
5. The instructor is able to related course materials to current issues or real life situations.	4.86	4.49	4.49
6. The instructor involves students with activities such as research, case studies, “hands on” application, etc.	5.00	4.32	4.35
7. The instructor provides different types of graded activities, exams, and projects.	4.86	4.37	4.37
8. The instructor is accessible for discussion of course topics outside class.	4.86	4.41	4.41
9. The instructor is clear in directions and explaining what is expected on assignments and tests.	4.86	4.48	4.46
10. The instructor encourages me to use multiple resources e.g. internet, library, etc. to reinforce my understanding of the subject.	5.00	4.36	4.43
11. The instructor respects the opinions of students	5.00	4.61	4.54
Overall	4.86	4.43	4.44

Conclusions:

Although the relatively low enrollment of this robotic course may reduce the significance of the survey results, it already shows some interesting results from the student survey and official course evaluation results. In Table 2, all the activities help the students to understand STEM, while the lab has the largest increase. One of the reasons is that most of the project activities are completed during lab section. However, the students do not have much influence by the activities shown in Table 3. Continuous improvement and future surveys may be needed to analyze how to further increase students’ interest in engineering and STEM fields. In Table 4, there is a 100% increase in terms of strongly agreement of “Integrating the Business Thinking into STEM project in this class will make the class more valuable to me” and some increases in the rest statements of Table 4 and Table 5, which may indicate the success of the improved curriculum. Meanwhile, this also the first time for both students and course instructor to implement the new curriculum, both parties may need more time to get used to the new curriculum as well. In general, the new

curriculum innovation has received positive feedback from students, which can be further approved from the official course evaluation results shown in Table 6.

Engineering education programs serves societal needs by preparing the future engineering workforce for careers in current increasingly globalized and technical world. Engineering education programs is facing significant challenges. There is a real need for curricular changes and other activities to engage, challenge, support and respect all students as a motivation for these to persist in their science and engineering studies. 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. The following challenges in the field of STEM education from pedagogy research point of view should be checked in our future project:
1) How to make meaningful and lasting impact on the chronic problem of inclusion of under-represented groups in engineering?
2) How to add skills in innovation and entrepreneurship without diluting engineering fundamentals given already over-crowded curricula?
4) Which STEM courses are most appropriate for introducing entrepreneurship related innovative curriculum materials?

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