Implementation of an Entrepreneurial Minded Learning Module Based on "Quantified Self" to Motivate Engineering Design in an Introductory Biomedical Engineering Course

Abstract

Entrepreneurial-Minded Learning (EML) pedagogy has been developed to emphasize students learning for discovering opportunities, creating value, gathering and assimilating information and utilizing feedback for design improvements. In this project, we set out to include EML in a freshman level *Introduction to Biomedical Engineering* course based on the theme of "Quantified Self". This is a new, exciting, real-world entrepreneurship opportunity that uses wearable sensor technology to help people understand their personal health and wellness.

The goal of this project was to develop and implement teaching resources that used the Quantified Self theme to motivate engineering design topics. Direct and indirect assessment was used to gauge the effectiveness of the module in changing students' perceptions and improving their entrepreneurial mindset. The module was a multi-week assignment that was implemented using Project Based Learning (PBL) techniques. It also included smaller in-class Active Collaborative Learning (ACL) activities and homework assignments.

The project started with an introduction and investigation of Quantified Self devices. Then groups were formed to practice opportunity recognition through the "Painstorming" technique [ref]. Thereafter, the groups were given a Nike+ Shoe Sensor system to develop a new application for this technology. Each group produced a device concept, a simple business model and evaluated the market potential. The assessment was concluded with a student produced elevator pitch video on economic and social benefits of their proposed application.

This project is part of a curriculum-wide effort to implement modules into a variety of different courses so that students will be repeatedly exposed to entrepreneurship skills with an increasing levels of difficulty and expectation. Ultimately, these modules are designed to enhance students' ability to recognize societal needs and also improve preparation for senior capstone design.

Introduction

Traditional engineering curriculum and coursework lacks entrepreneurial experiences for students as related to opportunity recognition and communications. But recently, many engineering colleges and foundations have promoted the idea that "Entrepreneurship is a Mindset" that can be formalized in engineering education (Rae, 2005; Kriewall and Mekemson, 2010). The

aim is to develop students who are better at adapting to new trends, embracing creativity and leadership, understanding engineering impacts on society and business, as well as providing more opportunities to experience engineering design (Fairweather, 2008). Engineering design courses at the freshman or senior levels are the most common way that universities use to give students opportunities to work on real world engineering problems (Shartrand and Weilerstein, 2012). Entrepreneurial-Minded Learning (EML) pedagogy provides engineering faculty with a useful and effective tool for embedding modules within other existing courses. The EML pedagogy has been developed as techniques that emphasize students learning to create value, gather and assimilate information to discover opportunities or insights for further action (Melton, 2014). EML also promotes inductive learning and allows students to explore the "why", "real-world relevance", and "impact" of the problems that they are asked to solve.

The "Introduction to Biomedical Engineering" course provides an overview of biomedical engineering, principles of living systems, engineering applications of bio-molecular and cellular fundamentals, and medical engineering. The societal value of biomedical engineering and the biomedical engineer's role in society are also important topics. The format for the class includes lectures, class activities, group discussions, group projects, and invited speakers. Over the past five years, faculty at XXXX University have been participating in workshops and had Kern Entrepreneurship Education Network (KEEN) Foundation support to revamp specific courses with ACL, PBL and EML modules (Carpenter et al., 2011). The "Introduction to Biomedical Engineering" course now includes short, in-class ACL activities throughout the semester as well as a few multi-week PBL assignments. While many of these learning activities have been adopted from other faculty (Prince, 2004; Smith et al., 2005), this paper reports the development and implementation of PBL teaching resources that used the theme of "Quantified Self" (QS) to motivate engineering design and entrepreneurship topics. The module combined several open-ended tasks that built sequentially following previously completed work and the topics that were covered in class.

The QS theme can be described as a social movement and/or a consumer electronics trend. This is a new, exciting, real-world entrepreneurship opportunity that uses wearable sensor technology to help people understand their personal health and wellness. QS is experiencing tremendous growth through the interest of large consumer electronics companies as well as new digital health startups. This explosive growth has been made possible by the convergence of technologies such as sensors, computer miniaturization, big data and widespread participation in social networks that allow sharing of personal information (Figure 1). By adopting QS as a running theme to motivate a variety of academic topics, students are given an opportunity to develop a mindset that fosters creativity and collaboration (Meyer and Nasir, 2015).

Figure 1: Representation of the broad range of topics that can be related to the QS theme.

Activity Details

The activity was introduced in Week 7 of the semester and culminated in Week 11. The following learning objectives were emphasized with the module:

- Opportunity recognition
- Define problems, opportunities, and solutions in terms of value creation
- Market investigation
- Anticipate technical developments by interpreting societal and economic trends
- Identify new business opportunities
- Create a preliminary model
- Communicate engineering solutions in economic terms and with regard to societal benefits

Nike, Inc. developed the Nike+ Sport Sensor with four pressure sensors and 3-axis accelerometer to go under the insole of athletic shoes (Figure 2). Initially the sensor and the accompanying shoe was marketed for basketball and cross-training but the product did not see widespread adoption in the marketplace. Nike+ sensors were donated by Nike for a storyboard competition. Student groups were led through a series of steps with the ultimate goal of creating a new product concept based on the Nike+ sensor technology.

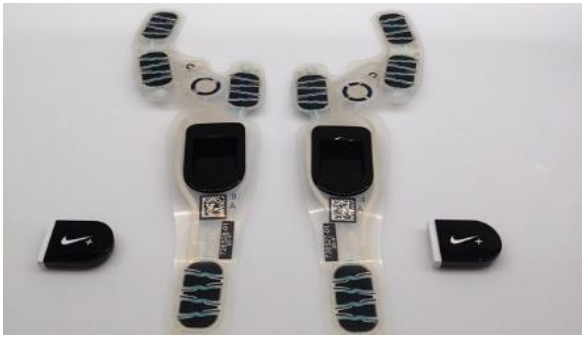

Figure 2: Nike+ "Hyperdunk" Sport Sensors that were given to student groups

Assessment Methods

Direct assessment of the assignment questions and final pitch videos was completed to determine if the students addressed the engineering design steps. Indirect assessment of the students by means of confidential, pre and post module surveys were used to gauge the effectiveness of the module at changing students' perceptions and improving their entrepreneurial mindset. Each question was ranked with a five point Likert Scale (1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly agree) and the average rank for the class at each time point was determined. The two time points were compared with an unpaired t-test and a value of $p>0.01$ was used to determine if the differences were significant. The surveys had ten questions related to their experience and capability to practice specific entrepreneurial skills during engineering design projects:

1. I have experience using some of the Entrepreneurship Skills to complete engineering projects.

During previous engineering projects, I have used the following entrepreneurship skills:

2. Define problems, opportunities, and solutions in terms of value creation.
3. Anticipate technical developments by interpreting surrounding societal and economic trends.
4. Identify new business opportunities.
5. Apply creative thinking to ambiguous problems.
6. Apply systems thinking to complex problems.
7. Examine technical feasibility, economic drivers, and societal and individual needs.
8. Communicate engineering solutions in economic terms and with regard to societal benefits.
9. Substantiate claims with data and facts.
10. Collaborate in a team setting.

Implementation

During the first week of the module (Table 1), in-class activities included a review of previous class topics of biomechanics, bioinstrumentation, and the engineering design process. Examples were given to practice opportunity recognition through the "painstorming" technique . Next, the theme of Quantified Self was introduced with a five minute TED talk video by Gary Wolf[1], presentation and discussion of examples of QS products (Figure 3). Finally, an individual homework assignment was given with guided questions:

- Find a product/service relating to "Quantified Self".
- Describe the "Quantified Self" device you chose.
- What need does this device address? What is the value of this device to the consumer?
- Give some details about the manufacturer. What is the value of this device to this company?
- Come up with one important feature that is missing from this device or think of an improvement that would make this product more valuable.
- Is this a good way to find about needs? Why or Why not?
- As an entrepreneur, why would be you be doing this step?

1. https://www.ted.com/talks/gary_wolf_the_quantified_self?

Figure 3: Introduction to QS presentation slides with examples for in class discussion.

During the second week, after reviewing other examples of QS devices, the students formed groups of 3-4. The technical capabilities of the Nike+ sensors and some of the marketing history for this product was introduced[2]. Each group came up with a list of at least 20 customer needs that could be addressed with a product that used similar technology. Finally, the groups were given a Nike+ Shoe Sensor system so they could increase their familiarity with how it worked. The second homework was a group assignment to produce a device concept, business model and evaluated the market potential following another set of guiding questions:

- Select one customer need that has the value proposition with the highest potential. Who is your customer? Justify why you chose this customer need.
- Develop a new product/service concept that utilizes the Nike+ Sport Sensor Kit. This development should include design sketches/storyboards/simulations about what the product/service looks like and how it would be used.
- Develop a business model around this product/service. What are the business costs and what is the price for consumers, or how would you generate revenue?
- Do you think that your customer target would be interested in purchasing and using this product/service? How would you validate this claim?
- Prepare a short (3-5 min), informal (no slides) group presentation to give during class.
    - Customer needs
    - Value proposition
    - Product/service concept
    - Business model

During the third week, each group presented their initial ideas to the class. The other students and faculty acted as the targeted "customer" to give feedback and to help the group improve their ideas. The last group assignment was to formalize the information presented in class into an interesting story and refined "pitch" that described the concept and business model and could be given to potential investors. Pitch videos were to be recorded that were similar to QS examples shown in

2. http://news.nike.com/news/nike-gameonworld

class from kickstarter.com or nikefuellab.com. Students used their own video recording and editing resources and were directed to consider adding background music, narration, text, backgrounds, close-up and wide angle shots. Finally, they uploaded the videos to YouTube.com.

Table 1: Course schedule of QS module activities. Presentation slides and assignments can be found at the website, XXXXX.

Week	In class	Out of class
7	• Painstorming activity • Introduction to QS presentation • Think-pair-share of QS examples	• Individual assignment to find another QS example
8	• Class discussion of other QS examples • Form groups of 3-4 students • Introduction to Nike+ Sensors • Group assignment to brainstorm and develop customer needs/value	• Group assignment to develop a product/service that uses Nike+
9	• Create company and motto • Informal group presentations with class feedback acting as a "customer" • Introduction to making a pitch	• Group assignment to create a pitch video
10	• Project recap and viewing of videos	

Assessment Results

Five groups completed this engineering design project during the pilot implementation. Most students understood the importance of design in engineering and were able to communicate their product concept in terms of technical capability, customer value and economic viability. Video quality varied between groups but the emphasis was on content and not quality. There were group participation and cooperation issues in one group, mainly due to student absences and missing the in-class components of the project. The other four groups produced good or excellent work on the assignment questions and final pitch videos. In general, the engineering students were more comfortable with written assignments, but the communication of an idea in terms of economic and social aspects was challenging. The survey results showed improvement in the student's perception for specific entrepreneurship skills (Figure 4).

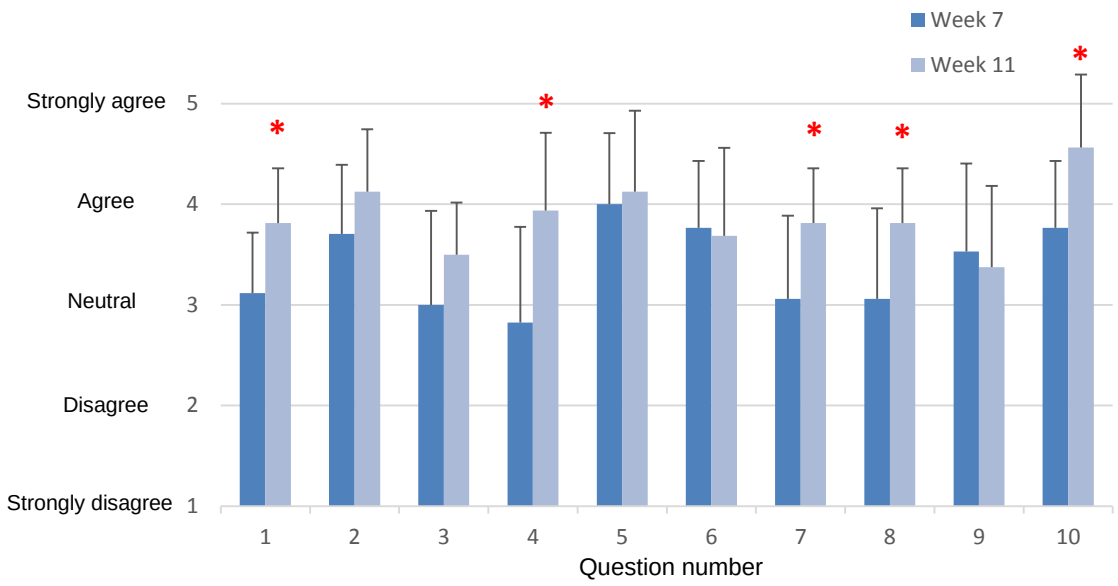

Figure 4: Indirect assessment results of the Entrepreneurship Skills Inventory survey. * Indicates a significant difference based on an unpaired t-test ($p>0.01$).

Discussion and Conclusions

Assessment results indicated that the module was helpful at introducing and improving students' abilities with certain engineering design skills. Although most students had no prior experience with the QS devices prior to the modules, they were engaged by this theme and particularly with the Nike+ sensors. Other positive reflections included that they enjoyed the open-ended and real world aspect of this project. Clear step-by-step structure and good faculty communication with the students is very important during this type of project.

Some recommendations and improvements that were made following pilot module implementation include; begin engineering design and entrepreneurial skills training earlier in the semester, continue EML experiences throughout the semester and finish with a formal design project assignment at the end of the semester. Future work for this project includes implementing module revisions in subsequent course offerings. Additional assessment data will be collected and analyzed to more formally determine the effect of EML on student's entrepreneurship and technical skills.

We noticed a tendency of students to want to jump past the "Opportunity" phase of the engineering design process. Although the module was broken into 3 parts, to force students to investigate the market, get customer feedback and determine economic benefits for their concepts, this process was still rushed and uncomfortable for engineers.

References

Carpenter DD, Hayes K, Ward C, Gerhart AL. Assessment and evaluation of a comprehensive course modification plan. Journal of Engineering Entrepreneurship. 2011:2(2);15-34.

Fairweather J. Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education, National Research Council's Workshop Linking Evidence to Promising Practices in STEM Undergraduate Education, 2008, Washington, DC.

Kriewall T, Mekemson K. Instilling the entrepreneurial mindset into engineering undergraduates, J Engineering Entrepreneurship, 2010, 1, 5-19.

Melton D. Bridging the Knowledge Gap: KEEN Program Director Doug Melton on entrepreneurially minded learning from a student and faculty perspective. KEEN'zine. 2014:2;6-7.

Meyer EG, Nasir M. Fostering the entrepreneurial mindset through the development of multidisciplinary learning modules based on the "Quantified Self" social movement. ASEE Annual Conf Proc. 2015.

Prince M. Does active learning work? A review of the research. Journal of Engineering Education. 2004:93(3);223-231.

Rae D. Entrepreneurial learning: A narrative-based conceptual model. Journal of Small Buisness and Enterprise Development. 2005:12(3);323-335.

Shartrand A, Weilerstein P. Strategies to Promote Entrepreneurial Learning in Engineering Capstone Courses. International Journal of Engineering Education. 2012:27(6);1186-1191.

Smith KA, Sheppard, SD, Johnson DW, and Johnson RT, Pedagogies of Engagement: Classroom-Based Practices. Journal of Engineering Education. 2005:94(1);87-101.