AC 2009-1825: INCORPORATING AN ENTREPRENEURIAL MINDSET IN FRESHMAN ENGINEERING STUDENTS

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An engineer equipped with an entrepreneurial mindset contributes to business success, makes his/her company more competitive, and is generally more aware of business and professional opportunity. To instill an entrepreneurial mindset in our engineering programs (aerospace, biomedical, electrical, and mechanical engineering), we started exposing our students from very early i.e., the first semester of the freshmen year. We developed and deployed a module that guides the student in developing an abstract idea into a product concept. This module takes three to five lectures and is designed to be a cohesive part of the freshmen engineering curriculum. The module includes several case studies executed by the senior engineering students, inspiring the students to believe in their potential. One example case study illustrating the product development process is provided in this paper. The freshman students wrote a one-page summary of their product concept and entered into the I2P competition. This paper discusses the module components designed to help students overcome the challenges in conceiving innovative product concepts. Results of a survey given after the module shows the students found this module and the associated activity to be useful.

1. Introduction

A 2002 estimate detailed how approximately 460 million people worldwide start a new business or become new owners of existing businesses every year[1]. Wrighton[2] notes how universities with engineering programs must be the promoters of entrepreneurship, since we are uniquely positioned to train students who have the technical ability to effect change and harness new and existing science into new solutions for the opportunities and challenges presented by the world economy. Students with exposure to engineering entrepreneurship will understand vital business aspects including marketing and economics, and key engineering facets such as innovation and performance. Such an engineer synergistically integrates technical competence, customer awareness, business acumen, and social values. In addition, engineering students exposed to entrepreneurship early in their education have shown higher retention rates[3-6], higher GPAs[6], and improved *soft* professional skills, which are components of engineering entrepreneurship, even while their understanding of engineering as a technical field does not change[3,7]. A recent study[8] revealed how engineering juniors and seniors believe they should receive education about business and entrepreneurship throughout their college careers, even though their major is in a technical field. Traditionally, the capstone senior design projects in undergraduate engineering programs come close to exposing the students to the business aspects, but most projects are dominated by design and build activities. The customer needs, business, and societal aspects take a back seat while the projects focus on technical knowledge and ability[6].

Instead of taking the traditional approach, we are trying to incorporate the entrepreneurial mindset into all of our engineering students, starting with freshman engineering courses and ending with their senior design capstone courses. We decided to entice students by exposing them to engineering entrepreneurship from very early in their program of study, i.e., the first semester of the freshmen year. This strategy is inline with the observations of Bilen et al.[9] and Georgi et al.[7] who note that younger students are more interested in entrepreneurship. They also indicate that creativity should be central to any module. To this end, we have started to deploy an interactive lecture module composed of real-world examples and product opportunity identification challenges in the freshmen year. This module takes three to five lectures and is designed to be a cohesive part of the freshmen engineering curriculum. Students work on the

challenge throughout the semester and present their project at the end of the semester. Student teams are also encouraged to participate in the *Idea to Product* (I2P) competition (*www.ideatoproduct.org*), a student-led event founded at the University of Texas at Austin which aims to promote cross-disciplinary education for engineering, business, and intellectual property/law oriented students by holding an early-stage technology commercialization competition with cash prizes to develop the winning product ideas.

2. Key Elements of the Module

The module, entitled "Synthesizing core concepts for technology entrepreneurship", is composed of lectures intended to provide an overview of the product development lifecycle, including customer need identification, concept generation, concept development, scope expansion, and business plan.

2.1. Need Identification

To help students conceive innovative product opportunities in the need identification process, we used the concept of *suboptimal equilibrium*[9]. The term *suboptimal equilibrium* refers to a situation wherein the users are unsatisfied with the product/service, but continue to engage in its use. A typical user views the situation as an acceptable inconvenience. The motivation for changing the state is lower compared to the inertia of people. On the other hand, an entrepreneur sees an opportunity of moving the equilibrium to a higher level of value proposition. Martin and Osberg[10] present several examples to show the concept.

One of the examples we use for the freshman module is an every-day example of trash disposal. A typical user experience involves taking the bag from the trash can (may be located in the kitchen), going to the main trash can (in the garage or outside), leaving the trash, picking a new trash bag (may be under the kitchen sink), coming back and lining the trash can. The process completes with the optional step of washing hands. In this entire process, the user visits the trash can twice.

With an entrepreneurial mindset, one may decide to alter the equilibrium. The first solution that comes to mind is to redesign the trash can. The box with the trash bags can be affixed at the bottom of the can. When the bag is emptied, a new bag can automatically come out along railings which open and guide the bag. The user can then tie the new bag to the edge of the can. The new design has more value with its convenience of avoiding several tasks, including acquiring another trash bag from under the sink, forcing open the bag and then lining the can. Other approaches could be effective solutions as well, so the important thing is to see the opportunity. Many other simplistic examples can also illustrate the concept of *suboptimal equilibrium* quite well.

2.2. Concept Generation

The catchphrase for our concept generation stage is "design a penguin" with the rallying picture shown in Figure 1. "Design a penguin" succinctly captures the need for innovation in shape design for the success of any product. Apart from helping designers to implicitly understand the expectations i.e., innovation, it has roots in the theories of cognitive science.

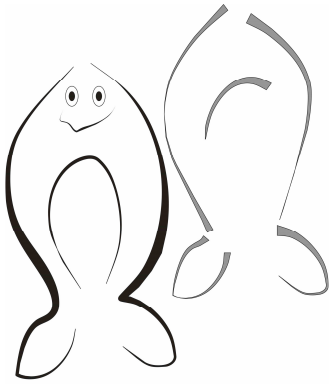

Figure 1: Design the penguin

The means for identifying the criteria of and the barriers to innovation lie within the realm of cognitive science. Humans *identify* objects by their resemblance to the prototypes representing knowledge categories. The prototypes are highly configurational and serve as typical examples of the category. For instance, we identify a robin as a bird because it "looks like" a bird (the prototype of the bird category). It is easy to recall birds like the robin that resemble the prototype more closely than unusual examples, such as penguins or chickens.

The same cognitive process plays an important role in achieving innovation[11,12]. The first solution to a design problem that comes to mind is usually a product that closely resembles the prototype, but is therefore less innovative. Designers must leave the prototype far behind to achieve innovation. While such movement may be difficult, it is essential. Consciousness of one's thought process can help in easily exploring other options and reducing the fixating effects of the cognitive prototypes.

The same recognition process differentiates an innovative product from others. To differentiate a product, besides superior performance, the product should look, feel, and/or function differently. This differentiation often creates resistance to acceptance in certain consumer segment. However, as long as the lead customers recognize the product innovation, the market shifts to the new product concept over a period of time.

2.3. Concept Development – Go beyond the initial idea

An innovative design is a synthesis of a series of good ideas, and not just one idea. Therefore, the entrepreneur must identify and integrate potential ideas into a few viable design concepts. Continuously evaluate the product concept and incorporate changes to make it robust. This development process slowly transforms a concept from a rough sketch into a concrete design.

During the entire process, make sure that the core underlying concept is innovative, viable from technical and economic points of view, and fits the overall scope of the project.

2.4. Expand the scope of innovation

Once you determine an innovative product concept, think beyond a singular product offering. Explore additional features and product contributions that will transform the product concept into a core concept from an enterprise point of view. In the short-term, the core concept will help to capture several different market segments and prevent the entry of the competitors into the market. However, with time, the product matures and the revenue begins to decline. If the core concept is good, it will provide a long-term competitive advantage by expanding the reach into other markets.

2.5 Business plan

Once the above items have been accomplished, we provide our freshmen students an overview of finance and marketing concepts that are required to formulate an initial business plan, i.e. how much will the product cost to build and produce, and how will the customer become aware that he/she needs this product. This is the final step before entry into the I2P competition.

3. A Case Study - VayuWind:

Energy crisis is one of the major problems that the world is facing today. On the supply side, fossil fuel supplies are depleting quickly. At the same time, in both industrialized and developing countries, the demand for energy is growing exponentially. Many countries are seriously developing renewable and nonpolluting technologies, such as wind energy, to solve their energy needs. However, harvesting of wind energy often occurs far away from the areas in need of power. An inexpensive method of tapping wind energy in cities and industrial centers in both developed and developing countries is much needed at this time. Tapping wind energy in an urban environment imposes different criteria such as low noise level, continually changing wind directions, and aesthetics on the synthesis of windmill design. In this project, the team decided to pursue a radical innovation strategy, deviate from the common windmill design – a horizontal-axis wind turbine.

For the windmill project, the team found identifying the market is more difficult as it required them to determine the market mindset and extrapolate the information to a larger degree. They found that in the last few years, natural disasters such as the tsunami in Indian Ocean and the catastrophic flooding of New Orleans have made the public more sensitive to the effects of global warming and fostered the understanding that every society must look beyond short-term economic considerations to work toward energy models that will shrink its carbon foot print. Al Gore's recent documentary *An Inconvenient Truth* and UN reports on global warming have moved the debate from the simple question "Is global warming real?" to the proactive question, "What can we do to reduce our (human) impact on the environment?"

The team concluded that the stage is therefore set at a societal level for the acceptance of innovative solutions that will combine efficiency with environmental ethics. Experts agree that no one technological solution can address all the complexities of global warming. What each society will need is a solution portfolio with a variety of technologies that can address the manifold challenges without requiring completely new infrastructure. Wind is a renewable, clean, pollution-free energy source with a nearly fixed cost. Apart from economic specifications for the market acceptance, in an urban environment, several marketing points become important:

1. Reflecting a green corporate image.
2. Noise level.
3. Being bird-friendly.
4. Adding appealing aesthetic element to city skylines.

The initial idea of the windmill group is to mount a wind turbine on a high-rise building. This exploits the existing structures to mount the wind turbine. From this common solution, the group deviated to propose their innovation to solve the problem– VayuWind – a hubless windmill that can be used effectively both in urban and rural environments. VayuWind deploys airfoils parallel to the rotational axis so that, unlike other vertical axis windmills, it rotates around a ring frame, leaving the central portion open for other uses (refer to Figure 2).

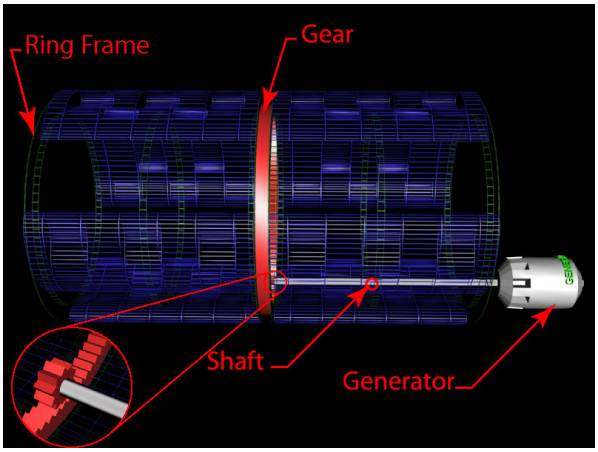

Figure 2: VayuWind design

The innovative design, VayuWind, extracts wind power using existing commercial buildings with minimal noise pollution. This concept is appealing for skyscrapers with significant energy demands because it generates electricity without taking up any ground space. Because the windmill is mounted on top of or around large buildings, the boundary layer close to the ground does not interfere with the air flow. The windmill design will add uniqueness and aesthetic appeal to both buildings and the city skyline (refer to Figure 3). The real-estate companies can capitalize on the green-image and charge higher rates for offices. These windmills pose minimal additional structural and real-estate needs. VayuWind can potentially revolutionize the use of wind power in everyday life by bringing windmills to urban centers.

Figure 3: VayuWind adding aesthetic appeal to the skyline

The VayuWind team spent time to think of product offering. Some innovative ideas include adding the windmill to skywalks and bridges to exploit the increased wind speeds due to the natural tunnel effect (see Figure 4). The team conceived additional microturbine categories to exploit institutions and residential applications (refer to Figure 5). In the residential applications, VayuWind product offering include an emergency windmill which helps to power a refrigerator and sump pump in case of emergency. Thus, the VayuWind provides a new value proposition and not just green energy and price point propositions. The long term product offering include Vayu Water to extract energy from ocean currents and Vayu Space to extract energy in the planetary exploration.

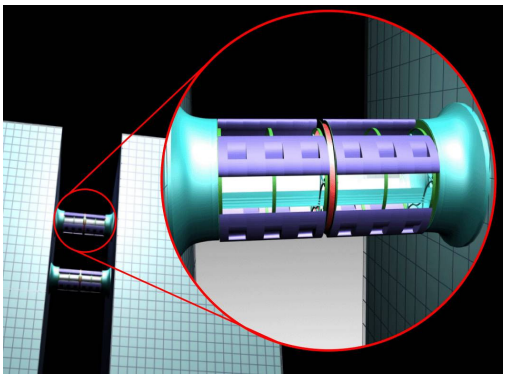

Figure 4: VayuWind for skywalks

Figure 5: VayuWind for institutional and residential applications

4. Discussion

An effort was made to introduce entrepreneurship concepts to all freshman engineering students for the first time during the Fall 2008 semester. Even though this material was being introduced for the first time, the students seemed receptive to the approach. Most students worked in groups of two and participated in the local I2P competition, judged by faculty from business and engineering schools as well as professionals from industry. This mix of judges is aligned with the suggestions of Watkins et al. [13] in order to provide a more rewarding experience for freshmen teams. It is noteworthy that two freshmen engineering teams going through this module placed in the top ten out of 64 entries from different schools within Saint Louis University, which included teams from business as well as our own aerospace and mechanical engineering senior design groups.

In the freshmen course, the students (n = 93) were asked to rate the effect of the module on their learning experience using a Likert-type scale: 5: Very positive, 4: Positive, 3: Neutral, 2: Negative, and 1: Very negative. Table 1 summarizes the results of the survey averaged over all five sections. Paired t-tests were performed and no significant differences were found between the five sections. From the data, while one may argue about the impact of the module on the entrepreneurial outlook, the module definitely made the students conscious of their creative side and business aspects.

	Mean	Std. Dev.
To view myself as an entrepreneurial person	3.61	1.34
To consider entrepreneurship as a career option	3.47	1.46
To view myself as a creative person	4.08	1.09
To aspire for creativity in future endeavors	4.28	1.07
To become conscious of business aspects while making engineering decisions	4.01	1.16
To think differently about the world around	4.05	1.24

Table 1: Summary of the survey results

In addition to providing an outlet for entrepreneurial activity, participation in the I2P competition also provided the students with an instant outlet for their creativity and allowed them to "do engineering" in their very first semester, which should prove beneficial in student retention as noticed by others cited above. Overall, we feel this module was a success in incorporating the entrepreneurial mindset into our freshman engineering students, and the module developed herein could easily be absorbed into any freshman engineering course.

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