Educating Engineers and Technologists for Innovation

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Abstract

The best way to equip students with the skills to lead and thrive in a global economy is to teach leadership, entrepreneurship, and innovation. Students can develop the skills to identify new business opportunities and develop the tools to capitalize on these observations through an active learning process. Universities can provide students with knowledge, and serve as the fuel for innovation and entrepreneurship [1]. Problem solving develops complex thinking ability in students [2]. In many industries technological innovation is now the most important driver for competitive success. Firms in a wide range of industries rely on products developed within the past five years for more than one-third of their sales and profits. Foreign competition has also put pressure on firms to continuously innovate [3].

Introduction

Innovation is the exploitation of change as an opportunity for a business or service. Innovation can be taught and learned [4]. On the average about sixty percent of all jobs in the U.S. are generated by firms with twenty or fewer employees. Large firms with over five hundred employees generate less than fifteen percent of all new jobs [5]. Students can also work for large companies as intrapreneurs within the large company. The Engineering Design/Analysis course at the University of Nevada at Reno provides an example of what one course in entrepreneurship can accomplish [6]. Student teams work during one semester to design and build an electronic device of some sort. Several of the designs were turned into real products that were sold to existing companies or formed the basis for new startups. Engineering students have to learn to engineer in a way that is ethical, socially conscious, environmentally sound, and globally aware [7]. Engineering education must make active learning the predominant engineering student learning mode [8]. Economic wealth is created through the creation, production, distribution, and consumption of products [9]. Most engineering and technology programs concentrate on building new products, whereas most business programs concentrate on the survey of potential customers and the business plan. This course emphasizes the product as well as the business plan, to develop a product that is feasible, profitable and meets customer expectations.

The Concept

Students can develop entrepreneurial skills by working in small teams to generate, evaluate, develop, and market their innovation. Faculty members should be encouraged to participate as student team mentors. At the beginning of the semester students in the innovation course will generate ideas for a large number of potential products. The product ideas will then be presented to the class and their peers will rate the ideas based on various factors given by the faculty. The product has to be prototyped by the end of the semester, so it has to be a project that is doable by the end of the semester. The project has to be at the skill level of the students. Students can imagine great projects, but they have to be able to make a prototype. The project cannot be too expensive, as it has to fit the budget of the school. Several other criteria can be added, depending on the limitations of the school. Students will then form teams based on product interest, compatibility, skills, and other factors. Problem solving, real-world experience, and designing artifacts develop complex thinking ability of students. Designing artifacts involves planning, inventing, assessing, and revising a product [10].

The teams will then perform a preliminary product and patent search, to make sure they do not duplicate an existing product. Once this is done, the teams will work together to generate marketable product concepts. Each team will then generate a survey for their innovative product. The objective of the survey is to identify the target market for the product. The teams have to then administer their survey to potential users. A cross section of the population would be ideal to get a good idea of potential clients. The survey will let the innovators know the most likely customers for their product. The objective of every team and every project will be to create, prototype, and market a new product. Once the team has decided on a project concept and objectives, they will work on developing their product. This will involve product specific development using engineering and business concepts. Product protection and marketing will depend on the school's existing policies and procedures.

Product Development

The process of taking an idea from initial conception to market is called product development. It includes idea generation, market research, product evaluation and selection, design and development, product protection and commercialization [11]. Traditional research methodologies are applied to developing a product and learning from the development experience. Developing a product demands the integration of content/basic thinking, creative thinking, and critical thinking [12].

Idea Generation

Idea generation refers to generation or identification of potentially marketable product ideas. Highly motivated enterprising students are an ideal source of potentially marketable, creative product concepts. Students will be motivated to pursue their ideas, especially when the potential for recognition exists. The opportunity to learn real business and engineering skills while working on one's own idea should appeal to many students. Even if student's concepts fail due to weak market analysis, existing products, or for any other reason, failure can often teach much more than success. The process most often used for idea generation is brainstorming [13]. This

involves students who suggest anything that comes to their mind, and feed off one another's ideas, and seeks to create a large list of potential products in an environment free of criticism.

During the first week, the students are told about how brainstorming is conducted in the lecture part of the class. Current students were also told about the products developed by previous students. They were also told that the best ideas were those that the students had a personal interest in developing, to fill an unmet niche. Once the list of potential products is developed, as in Table 1, students evaluate each product or concept, considering student interest in the project, strengths and weaknesses of the concept, feasibility of execution, etc. Students then form teams based on product interests, personal relationships, skills, or other factors. These teams will then work together to generate potentially marketable product concepts. Surveys or interviews with potential customers could be useful in generating relevant product concepts. Students must also be taught to keep an accurate log book and document their work carefully to protect their intellectual property rights. By the end of this process each team should have a potentially workable project. Once this process has been completed, the student teams can begin their market and product research, preparation of prototype, and preparing to present and defend their ideas before their peers.

Table 1: Brainstorming Innovative Products

PROJECTS	STUDENTS
1. Flood Stopper	Robert, Kenneth, Johnny, Sam.
2. Disposable Cap Liner	Larry, Vanessa, Ashley, Frankie, Daniel.
3. Under-Wire Bra Repair Kit	Sarah, Jennifer, Kristin, Aaron.
4. Jack-able Dolly	J. R., Roland, Rusty, Lisa, Ben.
5. Freeze Jug/Koozie	Brian, Garetti, Tyler, Nevena, Oved.
6. Breast Balancing Insert	Victoria, Mary, Wesley, Leo.
7. Ball Bearing Trailer Hitch	Randy, Will, Jared, Carlos.

8. Velcro Dog Collar	9. Child Beeper	10. Computer Strap
11. Cell Phone Capacitor Charger	12. Air Car Jack	13. Winter Jeans
14. Motion Detector Radio	15. Welder Wheels	16. Motion Capture
17. Tivo for Radio	18. Instant Omlette	19. Air Shoe Fix
20. T Post Remover	21. Dog Door Remote	22. Remote Finder

Market Research

During the second week, the students will perform searches to make sure they are not duplicating products already on the market, as in Table 2. If they plan on developing an existing product they need to show how their product is better than the existing product. The market research will let them know who their potential competition could be, and what would be an appropriate price range for the product. They should also consider demographic factors, establish timelines, and get a better estimate of the resources needed to complete their project. During the third week, the student groups make a timeline to guide the development of the product is shown in Table 3.

Table 2: Research Selected Products

Disposable Cap Liner - Daniel, Larry, Ashley, Vanessa, & Frank

- With the first reference www.halfbakery.com/idea/Disposable_20Baseball_20Cap _20Liners we discovered that the Cap Liner was already invented so we decided to improve this product.
- We were debating on what material to use, either Velcro or Magnet for the liner to stick to the cap. After finding that magnetic therapy has been used as a natural healing technique, we decided to use magnets to appeal to certain people who believe in this. The reference is: www.magnetsandhealth.com.
- What material to use was the next question? After researching different types of material we found that micro polyester is the best material to use because it helps keep your forehead sweat free. The web site was www.rockywoods.com/ micro_polyester.htm.
- We found that the cap liner had a patent. The patent # is 5566395. This patent had very good ideas that we did not think about like adding an antibacterial to the liner. The reference was www.freepatentsonline.com
- Micro fiber material was found on www.reviews.ebay.com/Microfibers-materials. We decided to use this material too. It is a fine synthetic fiber woven into lightweight, washable and breathable fabrics that hold shape extremely well.

Table 3: Project Timeline for Ball Bearing Trailer Hitch

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Brainstorming	X	X													
Research other Hitch		X	X												
Develop Survey			X	X											
Administer Survey					X	X									
Design							X	X							
Team Task List									X						
Gather Materials									X	X	X				
Prototype											X	X	X		
Complete Report													X	X	
Presentation															X

During week four the students develop a survey consisting of various questions designed to retrieve feedback from possible consumers about the marketability of the product, as in Table 4. The survey also collected information about these consumers and is designed to help the researchers forecast possible retail pricing and target populations. During week five, the students compile the survey results as shown in Table 5.

Table 4: Survey Instrument for Product

Breast Balancing Insert Survey

- Have you had or have breast cancer? Yes No
- Have you had or have a family member with breast cancer? Yes No
- Have you had or known someone that has had a lumpectomy? Yes No
- Do you have one breast significantly smaller than the other? Yes No
- Are you unable to wear shirts because of different sized breasts? Yes No
- Have you tried a breast balancing insert? Yes No
- Do you sweat in the breast area wearing a breast balancing insert? Yes No
- Would you be interested in a breast balancing insert? Yes No
- How much would you be willing to pay for a breast balancing insert?

  $50- $100 $101- $150 $151- $200 $201- $250 $251- $300

- For the purpose of demographics please answer the following questions:
- Gender: Male Female
- Age: Under 18 19-25 26-35 36-45 46-55 56-65 Over 65
- Income: Under $20,000 $20,000- $35,000 $36,000- $50,000
- $51,000- $65,000 $66,000- $80,000 $81,000- $95,000 Over $95,000
- Race: White African American Hispanic Asian Native American Other
- Where do you live?: Country City
- Do you have any suggestions to improve the breast balancing insert?

Product Evaluation and Selection

Once potentially feasible ideas have been generated and market analysis has been performed student teams must analyze their concepts according to some established criteria. The students then analyze the survey results during week six, to determine their target market as shown in Table 6. The evaluation criteria should include consideration of the product such as manufacturability, manufacturing costs, raw material availability, size, shape, material, color, price, projected sales volume, profitability, market strategy, adaptability to customer needs, and estimated cost of marketing. External factors to consider are market size, potential customers, competition, and demand. Internal factors include resources available, financial, equipment, time, and fit to program. In practice, this step is a filtering process in which only the ideas with greatest potential proceed.

Table 5: Survey Results

Survey Results for Jack-able Dolly

- Do you know what a Dolly is used for? Yes 53%, No 12.5%, Not sure 34%
- To move a large item, you prefer: Hand 0%, Hand truck 18.8%, Dolly 81%
- For a Dolly built in straps is a good idea: Yes 93.8%, No 3%, Depends 3%
- When moving which would be important:
- Rubber corners 43.8% , Move item by hand 15.6%, Quick moving 68.8%, Wheel locks 53%, Increase height 81% , Extra help 50%
- Use for a Jack-able Dolly for moving items: Yes 81% , No 18.8%
- How high you need an item to be lifted: Up to 1 foot 21.9%, 1 to 2 feet 28%, 2 to 3 feet 21.9% , More than 3 feet 62.5% .
- Interest in a Jackable Dolly: Yes 43.8%, No 12.5%, Depends 28%, Maybe 18.8%
- Which would you prefer: Manual 12.5% , Electric 28% , Depend on Cost 50%
- Spending amount on a manual Dolly: <$50 18.8%, $50 to $100 50% , $100 to $200 21.9% , $200 to $500 3% , More than $500 0%
- Spending amount for an electric Dolly: < $100 9%, $100 to $300 62.5% , $300 to $600 9% , More than $600 3%
- For purposes of demographics, please provide the following information.
- Sex: Male 62.5%, Female 28%
- Age: < 25 25%, 25-34 18.8%, 35-44 9% , 45-54 21.9%, 55-64 12.5%, >65 6%
- Occupation: Service 18.8%, Sales 3%, Manufacturing 3%, Industry 15.6%, Government 3%, Other 40.6%

During week seven, the students develop a business plan (www. sba.org), as in Table 7. An extensive business plan would be required if the group wanted to apply for a bank loan. The trailer hitch student group found from their survey that customers were willing to pay up to $ 300 for their product. Their product was a ball bearing trailer hitch for motorcycles, which would not topple the trailer during sharp turns. Some groups developed a more elaborate business plan, and others decided to price their product at the maximum the customers were willing to pay.

Table 6: Survey Analysis

Koozie Survey Analysis

- Our survey showed that 92 percent of the respondents knew what a koozie was and only 8 percent didn't.
- They are interested in a koozie that would keep their drink colder, for longer and are willing to spend from $0-5 for a koozie.
- We are mostly dealing with an age group that ranges between 18-25 years of age and prefer purchasing a koozie with their team's logo.
- The survey reveled that we are dealing with 76 percent white, 80 percent male, and 96 percent living in the city.
- Our survey clearly reveals that our product would be reasonable priced at around $4.50.
- If we stay within this price range, we can expect to sell 50 a week at $4.50 and maximize our profit.
- Our expense to make this product would be $2.00 leaving us with a profit of $125 per week.

Table 7: Preliminary Business Plan

The Business: Ball-Bearing Trailer Hitch

- Description of Business: Ball bearing trailer hitch for motorcycles and ATVs.
- Marketing: Create a website where customers can buy the product.
- Appear at bike shows and rallies.
- Advertisements in Gold Wing magazine and an ATV magazine.
- Competition: None
- Personnel: We will handle the manufacturing, marketing and distribution of the product.
- Financial Data (Prototype Cost):
- The total cost would range from about $32-$70 plus tax (8.25%) would equal $34.64-$75.58
- The work would be done by us (for prototype). Since the cost is roughly $75.58, if we charge triple since we are trying to turn a profit. The price we would charge is estimated at $229.99.

Product Design and Development

Starting with week eight and until week 15, the students work on the details related to the design and development of a particular product. This will also satisfy ABET (Accreditation Board for Engineering and Technology) Criteria 2000 [14]. Developing product prototypes will require the use of discretionary funds to cover the cost of materials, parts, and equipment usage. A task list should be developed to divide the tasks among the team members in the group as shown in Table

8. Project based courses prompt for reflection and use of experience from learning activities in the coursework [15].

Table 8: Task List for Product

TASK LIST for Flood Stopper

- Development of pvc pipe with shut off valve – Keith
- Develop control box to send signal to shut off valve – Kenneth
- Research other similar devices on the market – Keith, Kenneth, Sam, and Johnny
- Obtain costs for parts and labor – Keith, Kenneth
- Develop survey to test marketability of product – Keith
- Hand out survey questions - Kenneth
- Analyze survey results by calculating percentages – Keith, Kenneth
- Testing of completed proto-type – Keith, Kenneth, Sam, and Johnny
- Develop power point presentation – Keith, Kenneth, Sam, and Johnny
- Take digital photographs and put together presentation of all documents, research, and finding, along with working proto-type - Keith, Kenneth, Sam, and Johnny

Product Protection

Protection of products and intellectual properties by patenting or copywriting of new products are essential for long term survival and growth. However securing a patent can take up to two years and cost up to $10,000 in legal fees. Intellectual property policy protects the rights of all co-inventors. All participants must keep careful records of their activities in the form of engineering log books.

Commercialization

Once products have been conceived, selected, developed and protected, they must be successfully commercialized. The student teams are looking into commercialization options.

Evaluation

As each of the above steps is accomplished, every team should submit a brief informative report summarizing their activities for the current step, as well as laying out the goals for the next step. The key element in each report must be a summary of the work done to complete each step, broken down by team member, and a brief explanation of work to be done in the coming step. A formal presentation is done at the end of the semester to develop their oral communication skills, with a visual or actual demonstration of the prototype as in Figure 1.

Table 9: Project Paper Outline

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Figure 1: Presentation of Project (Jack-able Dolly)

Each team must also submit a final report outlining the development of their product and ideas for future development of the product, with an outline similar to Table 9. During weeks nine through 15, the student groups besides working on their project, also work on their paper. They usually complete work on their introduction on week nine, the methodology on week 10, product development on week 11, product testing on week 12, other possible products on week 12, conclusion on week 13, references in APA format on week 14, and the completed paper with the writing center checking their complete paper on week 15. At the end of the semester, all groups should submit peer evaluations. This will allow students to comment on the behavior, contribution, and people skills of their teammates.

Conclusion

This is the second time that I have taught a course on innovative product development. The first time I taught the course was with a group of 14 graduate students with backgrounds in manufacturing, electronics, graphics and management. They formed groups of three to four students and developed four innovative products. The 31 undergraduate students in this course were a combination of technology and business students. The seven groups had a combination of four to five business and technology students. In most of the groups, the technology students worked on the research and development of the actual projects. The business students worked on the survey, the survey analysis, the timeline, and the business plan. As was to be expected, the products developed by the graduate students were more complex than the products developed by the undergraduate students. This shows that the concepts can be taught at various levels. Only the scope of the project will vary based on the level of the students. The undergraduate students were given tasks to complete each week, to keep them on track to completing the project on time. Motivated students from any department should be permitted to participate. Having a wide diversity of students participate broadens the perspective of students by exposing them to think differently. It aids in the development of communication and interpersonal skills.

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Biography

RAJ DESAI is the Coordinator and founding faculty member of the Industrial Technology Program and Engineering Transfer Program in the School of Business at the University of Texas of the Permian Basin in Odessa, Texas. His interests are in the areas of innovation, and new technologies.