AC 2009-99: THE M.S.-M.B.A. PROGRAM: INTEGRATING ENGINEERING,
ENTREPRENEURSHIP, AND NEW PRODUCT DEVELOPMENT

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The MS-MBA Program: Integrating Engineering, Entrepreneurship and New Product Development.

Abstract

The MS-MBA program at the University of Tennessee was initiated in fall 2001 with a focus to provide students in Engineering with skills and knowledge of business focused towards new product development. National Science Foundation (NSF) provided funding for the program from 2005 to 2008 which helped enhance the program and led to development of several prototype products and commercialization of one the products Safelight™. The program has graduated more than 25 joint MS/MBA students so far with the number growing every year. The graduates have a double set of skills: entrepreneurship and business skills along with the advanced engineering skills needed to become leaders in innovative science and technology. The faculty associated with the program, who had limited previous entrepreneurial experience, gained insight into the role of entrepreneurship in bringing technology to commercialization and the role of intrepreneurship in larger technology companies. The program brought together faculty from the Colleges of Law, Business, and Engineering and formed synergistic relationships between the faculties of the disparate colleges that still exist. Some of the projects pursued under the MS-MBA program have addressed normal consumer-interest products, but several have also addressed medical/health applications and safety items. All potentially could or will contribute to society beyond just the satisfaction of academic requirements. This paper details the program and its components and can serve as a case study for other universities developing such programs.

Keywords: New Product Development, MS-MBA, multidisciplinary, entrepreneurship.

Introduction

The main aim of this dual-degree MS/MBA project was to further the economic development of the area by encouraging cooperation and coordination between academia and industry. As a part of this endeavor, the following main tasks were envisaged:

- Graduate Program Development
- Interface with College of Law
Graduate Program Development

The focus of this innovative dual-degree program was to integrate the skills and knowledge of students studying both engineering and business, and to direct those skills to product development. The intent was not merely to allow students to receive two graduate degrees in a compressed time frame, but to tightly integrate the two degrees so that multidisciplinary student teams would be able to develop an industrial product all the way from concept to market. The students obtained a Master of Business Administration [MBA] degree and a Master of Science [MS] degree in an engineering discipline in 23 months. The students worked in teams and were expected to have developed a concept, a business plan, a marketing plan and a prototype for a marketable product by completion of the program.

Development of two new graduate courses:

- **Product Selection and Evaluation / Innovation in Design  IE / ME 506**
  
  Course Description: Development of the operational requirements and features for a new product having the following characteristics: potential for business venture, market potential, design feasibility, and meeting manufacturing requirements. Design alternatives to be created and evaluated against a set of performance requirements determined from market analysis. Preferred product concept selected by the end of semester.

- **Integrated Product/Process Manufacturing System Design  IE / ME 508**
  
  Course Description: Presentation of different manufacturing system configurations. Exploration of relationships between product design and processing requirements, design specifications, and manufacturing costs. Finalization of design specifications and selecting processes. Analysis of manufacturing system costs. Presentation of factors affecting manufacturing system design. Case studies and team projects.
Ancillary Association with University of Tennessee College of Law

The interface with the University Of Tennessee College Of Law included the introduction of undergraduates to the legal aspects of business development by means of lectures by law professors. In addition, the College of Law assisted in the consideration of aspects of intellectual property issues related to the content of both the undergraduate and graduate courses.

These lectures covered three relevant areas of law: 1) tort law, focusing particularly on products liability law; 2) organizational structure on the issues involved in choosing the best organizational entity for a business (partnership, LLC, corporation); and 3) The basic areas of intellectual property (trade secrets, patents, trademarks, copyrights), and provided the students with a framework for recognizing potential intellectual property issues.

A class segment on choice of entity, focusing on defining the comparative attributes (taxation, governance, and third-party liability) of different forms of business associations, including partnerships, limited partnerships, limited liability partnerships, limited liability companies, and corporations was also conducted.

Development of "Idea Bank"

A team was involved in developing and maintaining an "idea bank" that includes ideas generated through the undergraduate and graduate courses. Careful thought was given to the aspect of intellectual property rights related to the use of the idea bank. A detailed procedure was developed with the involvement of the University of Tennessee Research Foundation (UTRF) and the College of Engineering, as described below.
The team's efforts were specifically focused on identifying and bringing together various "idea generators"--students, faculty, and third parties--with the aim of developing a systematic procedure of cooperation and coordination that would result in the selection and pursuit of an idea by student teams. A sample of an idea flow sheet that was developed to help define and systematize the development of the idea bank is shown in Figure 1.
The original flow sheet sought to find a mechanism by which the students and possible external inventors had as many options as possible for pursuing intellectual property (IP) protection for a given invention. Therefore, there were several decision points in the original flow sheet where the team had to decide if the idea from the inventor would be added to the database or if it would be held exclusively by an individual team. Also, the concept of “idea ownership” was promoted in the original flow sheet, with ovals indicating the “owner” of the idea (the team, the idea originator/inventor, UTRF, or some combination thereof). After a series of meetings with the UT Research Foundation, a single decision point was retained, at which the idea was evaluated by the UT Research Foundation for interest. The faculty involved in the program decided that the benefit of having UTRF involved in the process of writing and defending the patent outweighed any potential benefit from increased options for the team or idea originator. The resulting streamlined idea workflow is shown schematically in Figure 2.

Figure 2: Flow Chart of idea workflow
It was originally thought that a database of ideas would be valuable as a means of gathering and archiving ideas for future teams. A database shell using Microsoft Access was developed that could be made available and searched using a standard Web browser, with appropriate password protection. As discussed above, outside “idea generators” from the local community were brought in under signed non-disclosure agreements, and they presented ideas to the student teams. However, in the end, the student teams found their own ideas to be preferable and the ideas not generated by the teams themselves were not used. As a result of the experience of the faculty involved in the idea development and selection process, it was determined that the most effective strategy for generating and tracking ideas was a more informal process. The faculty involved felt that the number of teams involved did not justify the additional layer of complication, and so the online database was not used. However, for a larger group of teams, it may be a valuable resource. In any case, it would be necessary to determine how intellectual property from outside the University will be protected, who retains ownership of the IP, what are the implications for faculty involvement, etc. In our case, the additional complication of dealing with IP issues for ideas from outside the University led all of the student teams to use ideas generated by them.

Product Development and Commercialization Forum

The student teams’ ability to commercialize new products as they were developed was directly tied to their ability to identify a customer and industry need, as well as to develop a product that fit this need. In addition, the size of the potential market was found to directly impact the team’s ultimate ability to successfully commercialize a new product. For these reasons, the Product Selection and Evaluation process has become a critical component of the program. In addition, the ability to present product concepts to the entrepreneurial board (Table 1) and to leverage the participation of industrial partners is likely to extend the ability to commercialize products. Commercialization of new products occurs through one of the following avenues:

- Student teams' interest in creating a new company
- Licensing of intellectual property to a third party
• Industrial/private partners involved in the program
• Other independent entity

The student team's goals will be incorporated into the chosen path of commercialization, especially as it relates to the establishment of intellectual property rights, as noted above. The working relationship with UTRF is a key support structure to enable this process. When meshed with the individual goals of the student teams, the commercialization process can become a viable avenue not only for enabling technology transfer to the private sector, but also for enabling the near-term success of students who graduate from the program.

Entrepreneurial Board

The dual-degree program's start-up involved the cooperation of 20 public and private partners, including Oak Ridge National Laboratory (ORNL), large corporations, small start-up corporations, and state and local officials. Selected members of these partners (Table 1) were involved in the following activities:

• evaluating student projects and advising the student teams;
• offering the student teams technical and business expertise;
• contributing intellectual property (ORNL alone has a portfolio of over 1000 patents) and project ideas;
• serving as guest lecturers in graduate product-development courses;
• advising student teams, which involves attending student product presentations twice a year and asking 'hard questions' about the product, both on its technological feasibility and its market possibility.

Table 1: Public and Private Sector Partners (Participation Mode: 1 = Entrepreneurial Board, 2 = Product Development and Commercialization Forum)

<table>
<thead>
<tr>
<th>Organization</th>
<th>Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak Ridge National Lab</td>
<td>1, 2</td>
</tr>
<tr>
<td>TN Department of Economic and Community Development</td>
<td>1</td>
</tr>
<tr>
<td>Knox County</td>
<td>1</td>
</tr>
<tr>
<td>Center for Industrial Services</td>
<td>1, 2</td>
</tr>
<tr>
<td>UT Research Foundation</td>
<td>2</td>
</tr>
<tr>
<td>Analysis and Measurement Services</td>
<td>1, 2</td>
</tr>
</tbody>
</table>
Challenges Faced

Initiation and development of such an innovative and multidisciplinary program brought with it many challenges of both an operational and managerial nature. They included the following:

a) Developing a curriculum that could cover both engineering principles and business concepts within the tight schedule of an MBA program.

b) Marketing the program to industries to help them service their new-product development and commercialization needs.

c) Fostering cooperation among the various departments of the School of Engineering, College of Business Administration, School of Law, and ORNL regarding commitment of resources toward the success of this program.

d) Advising student teams along with asking “hard questions” about the products, both on their technological feasibility and their market potential.

This project can serve as a case study for other programs that want to develop similar MS-MBA degree programs within their schools of engineering, with the aim of fostering both technological innovation and commercialization.
**Teaching / Training**

The dual-degree program has contributed to a revision in the focus of teaching engineering. Whereas in the past, the engineering disciplines typically focused on the design aspects, the dual-degree program prompted us to blend design and business focuses. The course content has undergone revision to include a business outlook in the design. For example, concepts such as Quality Function Deployment (QFD) have been included in the course content in an effort to introduce customer-focused design. Similarly, the translation of product idea and product design to process design now includes aspects such as inspections to ensure reliability and quality as well as the consideration of cost aspects of the design. Tools such as simulation have been used to improve the process of integrating design and manufacturing functions.

The application of Lean Design principles to new product development courses has led the students to use Lean and Six Sigma tools at various stages when developing a new product. For example, a Lean QFD tool was preferred over simple QFD to define the product requirements during early stage of design. The Lean QFD tool was used to determine critical-to-quality (CTQ) measures and critical-to-lead-time processes to develop a Lean product right from the start, after defining the product requirements. Similarly the use of Six Sigma tools such as Design of Experiments and Failure Mode Effective Analysis were used to design the products at a detailed level in order to optimize design variables and predict failure. These applications of Lean and Six Sigma tools not only reduced the manufacturing lead time, manufacturing cost and time to market, but they also improved the quality of the new products. The new products were developed by maximizing the product performance from the customers' point of view, thus improving the market acceptance of new products.

A Lean product development course curriculum was developed with the help of the Center for Industrial Services, University of Tennessee, to educate the employees of small and medium-sized manufacturing industries around Knoxville. The outcome of the courses benefited various small and medium-sized industries by providing them all possible information regarding the process improvements that can be achieved by implementing Lean product development.
Industry involvement

The dual-degree program has enabled our courses to benefit from neighboring industries in the form of the involvement of industrialists and successful entrepreneurs as mentors and instructors to students. The influence of the industrialists has broadened the outlook of the students (and the courses) to look at the bigger picture. Industrialists served as guest speakers to introduce the students to a practical outlook on particular topics. The students thus got an exposure to the real world of business and industry through case studies and pragmatic advice from industrialists. The improved course content, with the direct influence from industry, induced an entrepreneurial focus in faculty and students.

Research

The courses that have been developed and taught have necessitated a new outlook on teaching engineering design and product development, particularly by including such "real-world" business aspects as customer-focused design, design for reliability and quality, and the cost aspects of design. These courses have, of course, resulted in the development of new products, but students and faculty have in the process gained experience in legal aspects such as intellectual property rights as well as design- and manufacturing-related legalities.

Based on the projects completed, a methodology for new product development based on the Lean Design approach was developed and involved the application of specific Lean and Six Sigma tools. This approach is aimed not only at reducing the manufacturing lead time, manufacturing cost, and time to market, but also at improving the quality of new products developed by maximizing the products' performance from the customers' point of view and improving market acceptance of new products. The proposed approach helps to identify and eliminate design waste that is neither visible nor serial and is observed only when the product reaches the manufacturing shop floor. A case study involving the design and development of SafeAlert®, a foot force-measuring device for orthopedic and lower-limb injury patients, is used as a model. The methodology is summarized in Figure 3.
Step 1: Define Product Requirements using Lean Quality Function Deployment (QFD)

Phase 1: Determining Critical to Quality (CTQ) Process using a customer interface (Questionnaire)

Phase 1a: Relates customer need to product technical characteristics
Phase 1b: Relates technical characteristics to the product part characteristics.
Phase 1c: Relates each product part characteristics to the process parameters required to achieve those characteristics.
Phase 1d: Relates each process parameter to a process step in part production.

Phase 2: Determining Critical to Lead Time Processes.

Phase 2a: The CTQ process steps are assigned times.
Phase 2b: The Delay times of CTQ processes are identified.

Step 2: Establish Product Line Optimization Team (PLOT) to determine how the new product will fit within existing material inventory, processes, factory layout and core competencies.

Step 3: Costing

Step 4: Design at System and Detail Level to fit the new design to existing and planned manufacturing processes using Six Sigma tools like DOE and FMEA.

Step 5: Design of the manufacturing environment for the product by integrating the manufacturing step with product development using simulation as a tool.

Figure 3: Lean Product Development Methodology

Products Developed

This section provides a list of products that were developed and brief description of the products.

Improved golf bag design with magnetic locking mechanism and rotational capability

The idea for this project was based on two separate needs expressed by the local golf community. The first problem was that expensive golf clubs often damage each other while in the golf bag. The existing solution to the problem is to use iron head covers. However, these head covers are such a nuisance to maintain and keep track of that most golfers would rather live with damaged clubs. The second problem was that many golfers who regularly ride a cart prefer to use carry bags. This is because carry bags are typically
lighter weight and can be stood up for storage, on the range, or if the golfer should decide on occasion to walk instead of riding a cart.

A working prototype bag was built and tested. However, a bag providing both of the functions addressed in this project appeared on the market about the time of project completion, so the product is no longer being pursued.

**Figure 4: Improved Golf Bag**

**Foot Force Sensor: Safe Alert Insole**

The SafeAlert insole was designed be worn as an inner sole in the shoe in order to help medical patients who have undergone lower-body surgeries such as hip or knee replacements or who have broken leg, ankle, or foot bones. The relatively simple purpose is to track the overall force that a patient exerts on the shoe insole and to warn the patient when the desired limit is about to be exceeded. It was developed through a working prototype stage. The device will provide instant feedback to patients when force-loading exceeds a value specified by the physician. Later versions are expected to provide additional records of information to the physician and should provide data to help explain slow healing, further injury, and any information relevant to liability suits. This device received the Pete Barile award for superior design in the annual University of Tennessee awards ceremony 2006.
BeatMinder

This invention is a tactile metronome called the "BeatMinder"; it is a musical time-keeping device designed to be felt rather than heard. It was inspired by the need of a piano teacher, Robin Trotter, who complained of students being unable to listen to both what they were playing and the metronome simultaneously. Her solution was to tap the students' bench or the students themselves in order for them to feel the beat of the music.

The first prototype version was based on an electromagnet. This design used an electromagnet and a permanent magnet, which were placed on either side of the upper cartilage of a person’s ear. Switching the electromagnet on and off produced a pinching sensation, conveying tempo information that could be felt by the user. A preliminary control circuit, case, and earpiece were designed in accordance with this new concept. The second version of the prototype was essentially a proof of the concept and was not yet considered ready for manufacture.
The final prototype was a more streamlined version of the second prototype. The control circuit was based on a PIC microcontroller, and a custom-printed circuit board was manufactured. An updated enclosure and earpiece were also developed.

![Prototype BeatMinder](image)

**Figure 6: Prototype BeatMinder**

**S-Tap Pumpless Keg Dispenser**

The S-Tap dispenser was an undergraduate design project to provide a means of dispensing beverages from a keg without the use of a hand pump, ice, or any power. The device used pressurized CO₂ to both dispense and cool the beverage on demand. A prototype was designed and built. Testing was not completed due to the lack of a licensed pressure-vessel test facility.

**N-Gee Digital Textbook**

The N-Gee digital textbook project was another undergraduate idea aimed at reducing the expense of college textbooks by downloading licensed copies of textbooks to a special reader. The license would be good for the period of the semester of use, but could be extended at additional cost. Specifications were written and conceptual design was completed. The project ended with the semester because competing hardware became commercially available.

**Automotive Door Retention System**

The Automotive Door Retention System is a mechanism designed to allow users to open a car door and brake it at an infinite number of positions, even when parked on an incline or when the door is subjected to high winds. The project stems from the problem
of doors closing on drivers or passengers in windy conditions, when parked on steep inclines, and/or when parked in close proximity to adjacent vehicles. A prototype system was built and tested, and revisions are under design. The participants intend to continue their efforts beyond graduation. This project won first place in the 2008 Pete Barile Design Competition.

Remote Residential Door Opener

This hands-free device allows virtually effortless, hands-free entry to one’s residence or place of business. This product combines RFID technology and dual mechanical gear trains into a new, innovative device that enables entry through a door even when one's hands are full with children or groceries, or when there is a physical disability that limits one’s ability to operate standard door hardware. A prototype system was built and tested, and revisions are under design. The participants intend to continue their efforts beyond graduation. The device placed a very close second place in the 2008 Pete Barile Design Competition.

Figure 7: Automotive Door Retention System
SAFELight™

SAFELight™ is a braking light system that provides an early warning signal for drivers in the event of an abrupt stop or extreme braking. The device uses standard OEM light bulb components with the addition of control circuitry and an accelerometer to detect when the driver applies brakes during a hard stop.

This product was recently sold to a small company interested in aggressively producing and marketing the invention. Safelight™ can now be purchased online at www.safelightstore.com.
Lighted Dental Mirror

This product team focused on developing an improved lighted dental mirror after evaluation of existing dental mirrors and input from two practicing dentists. The team developed a dental mirror with a 5 mm LED light source near the base of the dental mirror as an illuminating source instead of a large, bright light source focused on the patient.

Automotive LED rim lights

The motivation for this idea came from the fact that in the multi-billion-dollar aftermarket car accessory business, over half of the sales are dedicated to appearance-related products. The product is a set of replacement automotive wheels or attachments that would have a series of LED lights extending from the center of the wheel rim and culminating at the rim-tire interface. The lights would be controlled electronically so that the spinning wheel would create a persistent image for ease of visibility by other vehicles and pedestrians.
Conclusions

Entrepreneurship programs have been initiated in other educational institutions across the United States. Institutions offering dual degrees to undergraduate and graduate students in business and engineering are Penn State University, North Carolina State University, Mississippi State University and University of Colorado to name a few. These programs are similar to the MS/MBA program offered at University of Tennessee in terms of their goal to nurture the students in entrepreneurship skills. Apart from academics, the program at UT differs from other universities in terms of tapping the creativity of students through its unique IDEA bank and project collaboration with neighboring research organizations and industries. The whole idea is to encourage the students to enhance and tap their innovativeness from guidance from industry and academia and ability to work in and as a team.

The program brought together faculty from the Colleges of Law, Business, and Engineering and formed synergistic relationships between the faculties of the disparate colleges that still exist. Some of the projects pursued under the MS-MBA program have addressed normal consumer-interest products, but several have also addressed medical/health applications and safety items. All potentially could or will contribute to society beyond just the satisfaction of academic requirements.

The involvement of industrialists and entrepreneurs in the area to serve as mentors for the student teams and as instructors to share their knowledge and experience in their specific field of expertise, resulted in the development of an informal community of industrialists and academics which is sure to strengthen future developments in the region by contributing to each others' success.
## SAMPLE PROGRAM TEMPLATE

### DUAL MS-MBA

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<tr>
<td><strong>Fall – First Year</strong></td>
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<tr>
<td></td>
<td>Business Administration 512 (MBA Core II)</td>
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<td></td>
<td>Engineering Major</td>
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<td></td>
<td>MBA Innovative &amp; Entrepreneurship Elective</td>
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<tr>
<td><strong>Spring</strong></td>
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<td><strong>Total Hours</strong></td>
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