A Multidisciplinary Business and Engineering Course in Product Development and Entrepreneurship

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Abstract - This paper describes the design and development of a multidisciplinary course that pairs business and engineering students on teams for the objective of developing a new small product. The course is team-taught by faculty from business, engineering, and engineering technology. The student teams are required to develop a product concept, an engineering design, and a business plan. The major deliverables for the course include: an intellectual property search, a project proposal, a market analysis, a product requirement specification, an engineering design, a financial plan, and a marketing plan. The course culminates with a business plan deliverable that integrates all of these elements.

Index Terms - Business, Engineering, Entrepreneurship, Product Development.

INTRODUCTION

Penn State Erie, The Behrend College is a four-year college of Penn State University, located in Erie, PA, that has an enrollment of around 3,800 students. The Sam and Irene Black School of Business has a total enrollment of approximately 1,100 students and offers four year degree programs in Accounting, Economics, Finance, International Business, Management, Management Information Systems, and Marketing. The School of Engineering and Engineering Technology, with a total enrollment of approximately 1,100 students, offers four engineering degree programs in Computer, Electrical, Mechanical, and Software Engineering, and engineering technology degree programs in Electrical, Mechanical, and Plastics Engineering Technology.

The Product Development and Entrepreneurship course is part of an effort to develop a long-term business and engineering educational partnership that benefits both schools. The course has been offered twice so far. Enrollment is restricted to senior level students, since they have the prerequisite skills deemed necessary for the course. Business students who enroll in the course are typically pursuing degrees in Management, Management Information Systems, and Marketing. Students from virtually all academic disciplines in engineering and engineering technology have taken the course.

There are many opportunities and challenges associated with offering a multi-disciplinary project-based course with such a diverse student skill set. The major challenge is fostering multi-disciplinary teamwork; teams consist of students from both business and engineering, and within each team different business, engineering, and technology sub-disciplines are represented. The workload for this project-oriented course is significant, causing challenges for both faculty and students. The major benefit for the students is a unique educational experience where they work in an environment that is truly multi-disciplinary and where they are required to apply their educational backgrounds.

This paper addresses the objectives and content of the course; the processes used for team management; the processes and lessons learned by the instructors in team teaching a multi-disciplinary class; student feedback; and addresses future directions for the class and partnership.

RELATION TO PREVIOUS WORK

In the past several years there has been great interest in developing business and engineering curricula with a focus on entrepreneurship. The work by Standish-Kuon and Rice [7] provides an overview of some of the organizational models that schools are using to implement such programs. Within this scope, curricula and course are being developed, and one notable curricular effort is the Business-Engineering-Technology program at Auburn [9]. Some of the courses that have been reported are an Invention and Innovation course at the University of Colorado at Boulder in which teams of engineering students gain exposure to the design process and carry out business feasibility studies. At the University of Nevada, Reno, an Innovation and Entrepreneurship in Engineering course was developed in which student teams of senior electrical and mechanical engineers work with MBA students to develop a product idea and business plan [11]. At Brown University a two-semester course sequence in engineering entrepreneurship is offered in which engineering and business students develop a prototype project and business plan [4]. This is done under the guidance of local companies who provide the product idea [4]. An Integrated Product Development course is offered at Carnegie Mellon University in which teams of engineering (mostly mechanical), industrial design, and MBA students develop a product through program approval [2]. The development process is based upon Cagan and Vogel’s integrated New Product Development (iNPD) process [3]. The final example presented is the Product Development and Engineering course at Carnegie Mellon University where students are required to apply their educational backgrounds.
Design and Development course taught to graduate engineering and business students by Ulrich and Eppinger [10].

The course described in this paper shares many common curricular elements with those reported, but has some unique features. First, the range of undergraduate students who take the course is truly diverse, and more so than seen in other programs. The range of student participant backgrounds was identified in the Introduction. We advocate the use of the House of Quality [6] as an excellent tool for facilitating communication between business and engineering students. The issues of teaching such a diverse set of students are addressed in the paper. The course has a weekend kickoff seminar where students work on team development, learn from successful entrepreneurs, and brainstorm to develop product concepts. In addition, there is a trade show held at the end of the course, where teams present their product concept to judges who evaluate them in terms of market feasibility, technical content, and sales presentation. Teams also conduct market research to demonstrate the viability of the product. We present a model for a modified business plan, referred to as the Small Product Realization Business Plan, that integrates business and engineering elements into a cohesive document. The course has also played an important role in the development of a regional business plan competition sponsored by the Ben Franklin Technology Partners and hosted at Penn State Behrend.

**COURSE OBJECTIVES AND STRUCTURE**

The first step in developing the course was to develop the objectives and outcomes. This occurred over a period of several months through many meetings between the business and engineering faculty members teaching the class. The major educational objectives for the course were determined as follows.

**Students who successfully complete the course should:**
- Understand and experience selected elements of the product realization process.
- Demonstrate that they can function effectively on multidisciplinary teams.
- Develop a complete business plan for the introduction of a new product.
- Have a demonstrated understanding of intellectual property and ethical issues associated with new product development.

In support of these higher level objectives, the following team-based outcomes were defined.

**The team should be able to:**
- Effectively brainstorm to develop a product concept.
- Conduct research on the proposed product and complete a comprehensive patent search.
- Develop a requirements specification for the product that meets the needs of the customer.
- Complete a basic market analysis.
- Develop financial statements.
- Develop a marketing plan.
- Generate and evaluate design options.
- Propose a feasible product design.
- Estimate the development costs of the product.
- Address product liability issues as they relate to the proposed product.
- Develop a business plan for the proposed product idea.
- Work effectively together.
- Apply conflict resolution strategies to resolve issues within the team.

To achieve these objectives and outcomes, six main subject areas were developed: the project proposal, the product specification, the engineering design, the financial analysis, the marketing plan, and integration of these elements into a business plan. Each phase is discussed in this section.

**The Kickoff Seminar & Project Proposal**

Perhaps the most challenging aspect of the course is the selection of teams and identification of viable product concepts. The expectation is that teams will develop a product concept that is both novel and has reasonably good marketability. The first several lectures of the course are devoted to student introductions and brainstorming on product concepts. Brainstorming starts on the very first day. The ideas generated are posted on an electronic bulletin board where students continue brainstorming outside of class. Each student is required to develop a short resume and post it on the bulletin board. The students also make a five minute pitch in class to sell both their skills and themselves as a valuable team member.

After the first week of lectures, the students and faculty teaching the course participate in an intensive two-day off-site seminar. The teams are selected by the faculty members prior to the seminar. This selection is made based upon the student’s skills, interests, and a survey where students identify potential team members. The objective of the seminar is to kick start the team development, allow the students to interact with successful entrepreneurs, and to continue brainstorming. In terms of teaming, students are exposed to fundamentals of team development, participate in team-building exercises, and develop guidelines for team self-governance. There are seminars given by three to four successful entrepreneurs from different industries, with a focus on the development of new technology-based products. However, one of the popular seminars is by an entrepreneur who successfully developed a unique restaurant business model. A video of the ABC Nightline segment on the IDEO product design company and their development processes is shown [1]. It is rated highly by students and faculty. There are also sessions for team-based brainstorming, and by the end of the weekend seminar the teams are expected to have identified three to five top product ideas for further research.

After this, the course returns to a somewhat traditional format. Lectures alternate between the business and...
engineering faculty, but time is devoted in class for application of the concepts presented. Some lectures are set aside for the teams to work on the course deliverables. In this phase there are modules taught on intellectual property, patents, and market research. The teams are required to conduct preliminary market research on their leading product concept. The major deliverable for this phase is a Project Proposal that includes a competitive product analysis, an intellectual property search, and results of the preliminary market survey. This occurs within a four week period, and it is therefore critical for preliminary market research to start early on.

Specification Development

After the proposal is accepted, specifications are developed for the product concept. The driver for specification development is both the customer needs identified in the initial survey and technological considerations. The specifications are critical since they define what the product under consideration must achieve to be successful. Development of the specifications is also a focal point where both the business and engineering students must clearly communicate with each other and express their expectations for the product. This is no different than the challenges faced in an industrial setting. The House of Quality [6] and specification processes developed by Ulrich and Eppinger [10] are used to facilitate this. In the end, the teams are expected to develop both marketing and engineering requirements and identify the linkages between them.

Concept Generation and Design

Creativity and innovation are themes that are stressed throughout the course as essential elements of entrepreneurship and product development. Formal methods of concept development and evaluation are presented, as well as fundamentals of engineering design. Concept development focuses on brainstorming, formal methods of concept generation, and evaluation using decision methods. Basic concepts of engineering design such as functional decomposition are taught. The material is presented to be accessible to some extent by students from both of the main audiences, although some of the more advanced concepts may not be accessible to both. The teams are expected to develop a feasible design, but are not required to bring it to physical realization. That is generally not possible in a span of a 15 week semester, although some teams are able to construct prototype systems.

Financial Analysis and Plan

The teams develop a financial analysis and plan for producing, marketing, distributing, and selling their product. In order to successfully do this, they have to agree upon a model for development of the hypothetical business. In doing so, they have to answer many questions. How do they envision creating the startup? How many people will be involved? How will people be paid? How will it be manufactured? How much will it cost to develop and manufacture the product? What are the distribution channels? How will it be marketed? What is the selling price and break-even point? They are not easy questions to answer, particularly in such a short time period. To support this, cost estimation and the basics of developing financial statements are taught. This is supported with case studies showing different entrepreneurial business models. It is expected that the final submission for this phase is realistic and reasonable. Common flaws are underestimation of costs and overly optimistic profit projections.

Marketing Plan

The marketing plan focuses on the “Four P’s” of developing a marketing plan: Price, Product, Promotion, and Place (Distribution). The product aspect addresses a description of the product, identification of the need, a competitive analysis of existing products, and the argument for development. Price addresses competitive pricing, the product cost and the near and long-term pricing strategy. Promotion includes how the product will be advertised, publicized, and marketed. Finally, placement considers how the product will be distributed to the consumer and the channels that will be utilized. The teams also provide samples of professional promotional material (websites, brochures, poster-boards, etc) that market and promote their product.

The Small Product Realization Business Plan

The final deliverable for the course is a business plan that is tailored to the objectives of the course. It integrates all of the major deliverables into a cohesive document. This approach allows the teams to refine their work and correct previous deficiencies. The fundamentals for creating a business plan are covered throughout the semester through readings in a course text [5] and lectures devoted specifically to the essentials of a business plan. The format of the final plan departs from that of a traditional business plan and is included in the Appendix.

The Trade Show

In the last week of class a mock trade show is held. The objective of the trade show is for teams to present their work as they would to potential investors who are interested in funding their business. Each team sets up a table with promotional materials and makes a ten minute presentation to the judges. Judges for the competition are faculty and administrators from the business and engineering schools (the course instructors are not included as judges). The judging criteria are based upon the quality of the presentation, ability to answer questions, product viability, sales table layout, and the sales presentation at the table. The judging results factor into the final course grade.

TEACHING TO A COMBINED BUSINESS AND ENGINEERING AUDIENCE

Teaching strategies need to be adjusted to teach to a diverse audience with such varying backgrounds. First, it is expected that students from each schools bring their own expertise to
the project. Therefore, it is not the intent to teach all concepts at a highly detailed level. For example, it doesn’t make sense to have engineers become the experts on marketing plans, or for business students to become engineering designers.

This means that the business students take the lead responsibility in completing the market analysis and marketing plan, but the engineering students should develop enough of an understanding to critique the work and suggest improvements. The converse is true of the engineering related deliverables such as the specifications and engineering design. This approach mimics what students experience in the business world – team members working together to leverage complementary strengths to complete a project. The expectation is that students understand the basic concepts from the other field and develop the ability to communicate effectively between the fields. Regular quizzes are administered to the entire class to ensure that all students are gaining a basic comprehension of the material.

LESSONS LEARNED

A great number of lessons were learned in the two semesters that the course was taught. One of the main objectives for the course is for students to learn how to work effectively on multidisciplinary teams, and this is perhaps the greatest challenge. The weekend seminar is highly valuable in encouraging early bonding of the team. Team challenges were incorporated, such as building spaghetti and marshmallow towers and the prisoner’s dilemma [12], as well as opportunities for brainstorming and for socializing. Teamwork opportunities were increased in the second offering of the seminar based on student feedback after the first offering. Results of a short student survey conducted at the end of the weekend seminar support the perceived improvement by the faculty.

It is also valuable to require teams to develop self-governance guidelines that address how they will make decisions and resolve conflicts. This pushes the teams to take responsibility for self-management. They are required to apply the guidelines to resolve conflicts before approaching the instructor with a team problem. The teams are allowed to update the guidelines as the semester proceeds.

Each team is also assigned a faculty advisor after the project proposal is accepted. The role of the advisor is to evaluate progress, provide guidance, and help them perform effectively as a team. However, the teams are encouraged to see all faculty members teaching the course for questions regarding the different deliverables. They are also encouraged to seek outside expertise from faculty who do not teach the course, and often do.

The Small Product Realization Business Plan is used as the primary focal point for the course. This is because there are a wide variety of topics that are covered by three faculty members. The requirements for the business plan are presented early in the course, and the students are frequently reminded that it is the target for the course. During the initial course offering, all faculty members attended all of the lectures. That occurred in the second offering to some extent as new material was developed or rearranged. This was critical for establishing cohesiveness of the course material.

From a student viewpoint, the course is time intensive and requires much team interaction. In the second offering, the faculty identified methods for reducing the load, and will continue to do so while trying to maintain the integrity of the course objectives. A clear schedule of deliverables and the requirements for the deliverables helps the teams in managing their time. Such a course is always going to be challenging and time-consuming. The expectations and time commitment required for the students to master the material should be made clear up front.

From a faculty perspective, there are many challenges in team teaching this course. First, it is time-intensive to develop a completely new course and coordinate between multiple faculty members. It was important to have intensive preparation for the course and to develop clear objectives to make the course academically cohesive. This was particularly important due to the unique content of the course, for which there is no single textbook. A weekly meeting of the faculty members was a must in order to coordinate lectures, assignments, and continuously monitor the progress of the course. Now that the course has been established, the frequency of such meetings in future offerings will not be as great.

It is important to establish consistency of expectations among the faculty for the quality and content of student work. Written guidelines were developed for each deliverable, with the outcomes and content agreed upon by the faculty. A single faculty member was assigned as the primary contact for each assignment. This process evolved after it was found that students perceived that they were receiving conflicting advice on the deliverables. Typically, they were getting different perspectives based upon the background of the faculty member. That is a realistic scenario that they will encounter in their professional careers. The primary faculty member is responsible for grading the assignment. Some deliverables were evaluated by all faculty members, in which case the initial review is conducted by the primary faculty member.

BENEFITS

This course is time-consuming and challenging for students, yet most find it valuable. They have the opportunity to participate in a unique class and perform on a multidisciplinary team. Comments on the exit survey such as “I have learned the importance of teamwork” and “Learning how to work in multi-disciplinary groups was probably the most important thing learned in the class” support this. Preliminary feedback from students in the first course offering, who have graduated, indicates that they are finding it useful in terms of their work experience. One graduate stated “I learned to work with people who have very different priorities and concerns from myself. Despite all of our differences, we were able to work together to produce a viable product. As I entered industry, I realized that this did not end with the small product realization class, it became day to day life.”
At this point, no teams have produced a product that has been brought to market. Although that is an added benefit, it is not seen as critical to the success and objectives of the course. The faculty and judges of the trade show have identified several products that are believed to have commercial potential. In addition, some of the teams have gone on to compete in the external business plan competition sponsored by the Pennsylvania Ben Franklin Technology Partners (www.benfranklin.org). This collegiate business plan competition is held at Penn State Behrend partly due to this course.

The faculty experience in the course is similar to that of the students – it is time-consuming and challenging, yet ultimately beneficial. First, the faculty sees this as valuable in improving the educational experiences of graduates from both schools. It has a particular importance in the Northwestern Pennsylvania community where the university plays an important outreach and economic development role. Teaching the course also forces the faculty to practice what they preach - that multi-disciplinary teaming is valuable. This effort is also recognized in our environment as valuable to both schools and the college.

**SUMMARY AND FUTURE WORK**

Offering this course offers a great benefits and many lessons were learned as indicated in the paper. One of the critical aspects is the ability to integrate true multi-disciplinary experiences for business and engineering students. The experiences are realistic and help prepare students for their professional careers.

Sustaining cross-disciplinary academic efforts is notoriously difficult, often relying on committed champions. The faculty continues to look for ways to involve more faculty members from each school in teaching the course for long-term stability. There is currently more interest among the engineering technology and engineering faculty than business, a commonly reported phenomenon. However, we have been active in presenting the results of this work to our peers, and will continue to do so. Based upon this, more faculty members are expressing interest in participating in the course and using it in their curricular programs.

Currently, the course is accepted as an elective in the business, engineering, and engineering technology programs. There is evolving interest in applying the course on a trial basis for the engineering and engineering technology capstone courses. Many of the learning objectives overlap with those of existing capstone courses. However, there is less emphasis on realizing the technical design, and more on multi-disciplinary teaming and entrepreneurship. That effort will be piloted in the next offering.

This course is part of a larger effort to develop an engineering and business educational partnership. Both schools are moving into a new facility, the Research and Economic Development Center, in 2006. The synergy developed by co-locating the schools together is meant to act as an incubator for unique academic programs and regional economic development. Another faculty team has recently completed an in-depth survey of the business skills that business desires from industry. Based upon the survey results, there is a pilot course being offered in Fall 2004 on project management principles for engineers and technologists. However, more work has to be done to determine the outcomes and offerings desired for such a partnership from the business perspective.

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**REFERENCES**

APPENDIX: THE SMALL PRODUCT REALIZATION BUSINESS PLAN

The contents and a short summary of the elements in the Small Product Realization Business Plan are described as follows.

Executive Summary

Summarizes the entire business plan and identifies key points from each of the sections in the report. Points included are the product description, opportunity, strategies, goals, and future opportunities.

1. Product Purpose. This describes the need and purpose of the product/service in fairly simple terms. It should be promoted as though the reader knows absolutely nothing about the product.

2. Unique Features. This section identifies features that are critical to the successful performance of the product. It is important to identify benefits to the customer.

3. Intellectual Property & Product Comparison. This section identifies existing patents and technologies that are similar to the proposed product. Differences and similarities of the existing technologies/patents should be addressed, as well as a discussion as to why the product is superior to what already exists. This is supported by a competitive analysis matrix.

4. Environmental Analysis and Industry Profile. This section should expand upon the competitive analysis, describing the Market or Industry, and Competitive Environment as it is today. SWOT analyses are encouraged.

5. Market Research. This describes the design of the market research instruments, for example, what the objectives in crafting the survey were and what was learned from the results. It should provide an analysis of the results and their implications. In an appendix, present the research instruments used, and explain why each question is relevant. Any statistical analyses should be part of an appendix. Based upon the market research, the target market or profile should be identified.

6. Product Design. The section provides a complete description of the design selected, as well as an analysis of the alternatives and technical tradeoffs that factored into the design. Elements included are the product specifications, the House-of-Quality analysis, the product design, and the evaluation of design options.

7. Constraints. This section identifies any standards and constraints that the product would have to meet. This may include government approvals, independent testing approvals, standards, and constraints on the design (economic, health & safety, manufacturability, social), and potential liability issues.

8. Marketing Strategy. This is the plan that describes how the team is going to market and distribute the product. Decisions should be related to the preferences and behavior of your target market(s). Areas to address include an augmented product description, how the price was determined, the pricing strategy, promotion strategies, and distribution strategies.

9. Financial Plan. The objective of this section is to present the complete financial needs for launching the product venture. It should describe the assumptions that went into the development of the financial plan. Elements to consider are startup costs, gross margin on product, break-even analysis, production, development, and manufacturing costs, labor, benefits, taxes, and suppliers.

10. Operating and Growth Plan. This section describes details about how the team would anticipate operating and growing this venture. Things to consider in this section are: timeline, justification for company ownership, personnel requirements, new offerings to the market and future opportunities, plans for strategic alliances, and an exit strategy.

11. Summary. Provide a summary of the key elements of the plan and recommendations for action to the audience.