International Journal of Engineering Education Vol. 28, No. 2, pp. 1–5, 2012
Printed in Great Britain

0949-149X/91 $3.00+0.00

Outcomes of Recent Efforts at Rice University to Incorporate Entrepreneurship Concepts into Interdisciplinary Capstone Design*

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Many engineering departments use the capstone engineering design experience to introduce students to additional skills that will be required of them in professional practice. Two skills that can help young engineers are the ability to work in interdisciplinary teams and a good understanding of the business implications of their work. Young engineers entering an industry job are likely to be immediately placed into a division or team that is comprised of people from a wide variety of educational backgrounds, including other engineering disciplines and, depending on the industry, individuals with business, marketing, public relations, policy or science backgrounds. While students often leave their undergraduate education with a firm grasp on the fundamentals of engineering, they often have not been trained to consider the business aspects of their work. This paper describes the efforts and early outcomes at Rice University to incorporate entrepreneurship concepts into our interdisciplinary capstone design program.

Keywords: engineering design; interdisciplinary design; entrepreneurship; capstone design

1. Introduction

Engineers can be better prepared for the challenge of working in industry if they have learned to think about the business implications of their technical work while in college. Gassert *et al* point out that while very few engineering programs explicitly incorporate entrepreneurship into their curricula, the same skills that are needed to be a successful entrepreneur are required to accomplish an engineering design task [1]. For many years, the National Collegiate Inventors and Innovators Alliance (NCIIA) has promoted the teaching of inventorship and entrepreneurship through course grants, students entrepreneurship team grants as well as through entrepreneurship competitions as a way to take ideas from concept to implementation with the ultimate goal of creating jobs and improving the economy [2, 3]. In addition, students who have learned to work effectively in interdisciplinary teams are likely to be better prepared to be successful in their future endeavors. Criterion 3 Student Outcomes (d) in the ABET Engineering Accreditation Commission requirements for engineering programs requires that engineering graduates must have a demonstrated ability to work on multidisciplinary teams [4]. It is a commonly accepted leadership principle that interdisciplinary teams will be more effective at achieving a desired outcome [5]. Additionally, there are reports from several groups that describe improved outcomes from interdisciplinary design teams [6, 7]. When students leave school, we expect they will also have an advantage over their peers who have not worked in an interdisciplinary team.

In 2008, the Rice University Brown School of Engineering opened a facility dedicated to undergraduate engineering design efforts. The primary goals for the facility were to: (1) provide a space where undergraduate students from each of the 8 departments within the school could work on their engineering design projects, (2) provide a venue for

* Accepted 20 August 2011.

departments enhance opportunities for students to work on real-world, interdisciplinary design challenges, (3) develop additional opportunities for younger undergraduates to participate in engineering design activities and (4) enrich design projects with practical training in topics such as entrepreneurship. The Oshman Engineering Design Kitchen (OEDK) has become a major hub for undergraduate engineers at Rice (Fig. 1). Student design projects can originate from course work or can be part of the effort of a student organization (e.g., Engineers Without Borders) or independent work. The OEDK includes a large central work area that consists of 36 individual work tables, design team storage space, three conference rooms—one with videoconferencing capabilities, a flexible design classroom, a computer lab, a wet lab, a machine shop, a student lounge, and a copy and print room. The OEDK also maintains several pieces of rapid prototyping equipment for student design team use. These include a 3D ABS plastic printer, a laser cutter, soldering station and a printed-circuit board mill. The OEDK is well stocked with equipment and tools that can be used by any of the teams to accomplish their projects.

In this paper we report the initial outcomes of our efforts to collaborate on a single capstone course that can be offered across several departments, our efforts to increase the numbers of interdisciplinary design teams, as well as the program that is used to introduce entrepreneurship to the undergraduate student teams.

2. Combined capstone course

Prior to 2008, the bioengineering, electrical and computer engineering and mechanical engineering departments had occasionally offered collaborative, interdisciplinary projects to their students. These efforts were sporadic and would only account for 2–5 teams (~10–15%) annually. These were challenging efforts because the various design classes had differing expectations and timelines that had to be modified to meet the needs of each department. In order to address these challenges, the three depart-

Fig. 1. Photographs of the Oshman Engineering Design Kitchen.

ments decided create a collaborative capstone course.

The collaborative capstone course for bioengineering, electrical engineering and mechanical engineering students has been taught for two academic years. Each department maintains its own official course, requirements, and instructor. However, the courses meet simultaneously approximately 75% of the time and share a course schedule, deadlines and deliverables. Table 1 shows the topics covered collaboratively. For each topic we choose the instructor best suited to deliver the material. In addition, we invite experts from across campus to teach specific material such as the business planning and teamwork modules. The best features of the individual courses were combined to result in a better course. Additional material is covered, as needed, by the instructor with his or her own students.

In addition, we have made a significant effort to offer and encourage the teams to work on real-world challenges. We define a real-world challenge as a project having an external stakeholder interested in obtaining a viable solution to the problem for actual implementation. This may be an industrial sponsor, physician, community organization, faculty or other professional. These challenges often require more expertise than an individual discipline may provide.

3. Entrepreneurship efforts in the combined capstone course

Working with the Rice Alliance for Technology and Entrepreneurship, we developed a compact 4-lecture module that introduces the following topics: (1) Business plans: Why do I need one? (2) Elevator pitches: Why do I need one?, (3) Business models and options: How will I make money?, and (4) Protecting your ideas. (See Table 2)

The students complete assignments in these areas by using their own design project as their case study. For example, students working on a global health design challenge might focus on a social venture model for their business plan. During the course of this module, each team develops an elevator pitch for their project. In addition to the course lectures,

Table 1. Topics Covered In Collaborative Capstone Course

Design process	Business planning
Communication and documentation	Elevator pitch competition
Intellectual property	Industry demonstrations
Leadership and teamwork	Life Cycle Analysis
Brainstorming	Engineering economics
Project management	Design of experiments
Project planning	Human factors in product design
Safety and environmental issues	

Table 2. Topics Covered In Business Module Of Collaborative Capstone Course

Class Title and Topics Covered
Business plans: Why do I need one? Class describes the various uses and function of a business plan. Who needs them?, Why are they needed?, Who writes them?, Who will read them?, What do you do with them?, What's in them? Details about common material that should be present in a business plan such as: Background & Purpose of Company, Market Analysis, Market Strategies/Forecasts, Product Development, Financial Data, Organization and Mgmt., Ownership, Critical Risks. **Handout A:** Detailed Business Plan Content Checklist. **Handout B:** Sample companies for selection.
Elevator pitches: Why do I need one? Class describes the various uses and function of an elevator pitch. When are they needed?, Who gives them?, Why are they important?, What is the impact of a good or bad elevator pitch? Class watches example elevator pitches from Rice Business Plan competition and Previous year's seniors.
Business models and options: How will I make money? This class describes various kinds of business models and how they can be sued to create a viable business. Will you sell, lease or rent to end users?, Will you sell or consign to distributors or wholesalers?, Will you license someone else to make and sell it?, Will you license to an independent entrepreneur?, Will you offer a service based on your product idea? Is your idea a platform technology?, Combine with other product for new product? Will your product be investable models versus Life Style models?, Will your product be offered through the internet?. What will be your assets?, How do you see the value of your technology?
Protecting your ideas This class describes an introduction to intellectual property, technology transfer, patents. Students learn to search first alternatives, competing ideas, and other works in progress. They learn to consider: How do you determine patentability?, Why or why not patent?, What are the patent options? (Provisional, Utility, Design, Plant), How should you look at branding?, How can you use trademarks?, When to use an NDA?, What does 'Know How' mean?, What are trade secrets ?, When is an IP an asset?

each team meets with a business coach to practice and receive advice on how to improve their pitches. The module then concludes with a major elevator pitch competition run in the same manner as the Rice Business Plan Competition.

Approximately 50 judges (mostly local entrepreneurs or investors affiliated with Rice Alliance) and an audience of 100–150 watch as each team pitches their product in 90 seconds. In order to build additional incentive, beyond evaluation for a grade, cash awards (total of $5100 in 2010) are offered to the top teams in the elevator pitch competition as evaluated by the judges. 71 teams have participated in this process in the past 3 years. Each year the module has been improved and expanded. The full elevator pitch competition has been run for the past 2 years. This year many judges remarked that these elevator pitches were of comparable or better quality than those in the general Rice Business Plan Competition.

4. Outcomes

A wide variety of positive outcomes have emerged from combining our capstone design courses. First, students have been able to successfully tackle design challenges that would be quite difficult to accomplish with students of only one major. As a consequence, these problems are often more realistic representations of the design work that the students will face in industry. Second, the deadlines and expectations are clear for all of the students and do not vary across students' major departments. Third, the course instructors have each contributed their expertise and developed a set of enhanced lecture content. This has resulted in a more comprehensive design course for all the students. Finally, we have been able to incorporate business planning, market assessment and entrepreneurship into the curriculum for all students.

The program has gone from having only a few interdisciplinary teams per year to having nine teams this year. This represents about 1/3 of all the teams from the three departments. The interdisciplinary teams have been more successful at accomplishing their tasks and earning design awards for their projects when compared to the single-discipline teams (Fig. 2). We are working to quantify these outcomes more precisely. We are also working to assess whether the greater success in earning awards is truly a consequence of working on an interdisciplinary team or if other confounding factors are acting. These factors include: (1) Are stronger students more likely to participate on interdisciplinary teams thus accounting for the differences in awards?, and (2) Are measures other than awards earned, such as quality of design solution, more appropriate measures of team performance?

On the entrepreneurship side, every student in the three departments now is exposed, at least to a small degree, to the concepts of entrepreneurship. We emphasize the importance for students—even those never intending to become entrepreneurs—to consider the business implications of their future engineering work. We do want them to learn how to consider the commercial applications, markets, and customers to enhance the quality of their designs, and to consider the competitive alternatives available in the market. These skills, and the skills of being able to communicate effectively and succinctly to a non- technical audience, will be useful whether they take a job in industry, pursue a graduate degree, or pursue an academic career. About 28% of past Rice alumni ultimately go on to start their own companies (based on historical Rice data), and gaining this broader education will improve their chances of being successful throughout their working careers. The students learn how to craft a short pitch that can be useful in many aspects of their professional lives. Additionally, based on their enjoyment of the entrepreneurial content of this module, several students formed a student club—the Community of Rice Entrepreneurs that aims to promote entrepreneurship amongst Rice students. This club worked with the Rice Alliance to start a full business plan competition for undergraduates pursuing technical ventures. Since the start of the business module 3, student teams have gone on to pursue businesses around their technologies. OrthoIntrinsics, Inc. won the national ASME iShow Innovation Showcase (a technical and innovation competition), has licensed their technology from Rice, has raised $250,000, and has made its first sale.

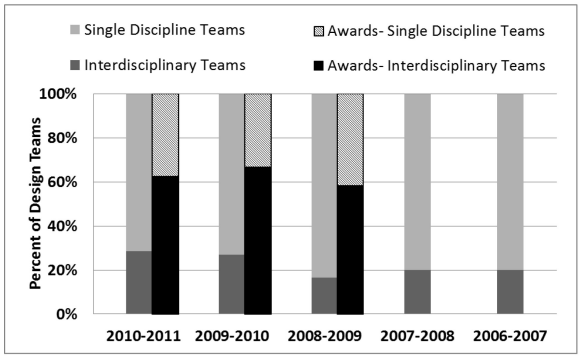

Fig. 2 (a) Proportion of single discipline and interdisciplinary capstone design teams in bioengineering, electrical engineering and mechanical engineering by year. (b) Proportion of award winning teams that were single discipline and interdisciplinary teams (note these results are only available for 2008–present).

An undergraduate student in our program teamed up with MBA students to form a team, InfantAir. This team based their business plan on a technology developed by this undergraduate and her capstone design team. InfantAir entered the national Rice Business Plan Competition (>40 top teams from around the world) and won the Social Ventures award. They have gone on to be awarded an eTeam grant from the NCIIA to further develop their business. A third student is working with his Rice faculty mentors to launch a fluorescence microscope product developed in the course.

5. Conclusions

While our program has made great strides toward incorporating interdisciplinary design and entrepreneurship for many of Rice's undergraduate engineering students, there are several ways to expand the program further. The course module and elevator pitch competition are now open and available for all capstone design courses at Rice. Because of the modular nature of the program, it can easily fit within other capstone design courses. In addition, we have found that by introducing the entrepreneurship concepts in class and providing additional opportunities for the students who are most interested, the students graduate very capable of developing into budding entrepreneurs. One student commented after participating in the elevator pitch competition: 'It was an intense, defining moment of my Rice experience. Having the opportunity to present to an auditorium of investors and venture capitalists is almost too good to be true. Thank you.'

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