AC 2007-2925: CREATIVITY AND NEW PRODUCT DEVELOPMENT: BRINGING ENTREPRENEURSHIP INTO ENGINEERING DESIGN CLASSES

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Creativity and New Product Development: Bringing Entrepreneurship into Engineering Design Classes

Abstract

We have taught a course on *Creativity and New Product Development* since 1995. It is unique in its attention to all aspects of the product development process, including the personal and interpersonal issues in product development, as well as the technical ones. Our focus is not just on studying product development, but on actually DOING it. The students develop a new product idea and carry it through to a physical prototype. They must also formulate a business plan, marketing strategy, and an appeal for funding. We bring in guest speakers with expertise in intellectual property issues and several successful entrepreneurs (including former students from this class). In this paper, we discuss the three versions of this class, and how they have evolved. We also discuss our students' successes, and some of the problems they have encountered in trying to commercialize their ideas.

Index terms - Creativity, new product development, entrepreneurship, distance learning

Introduction

The first version of our course *Creativity and New Product Development* was developed by Henry Bolanos and Dave Lewis. Henry is an inventor and entrepreneur, and Dave is a mechanical engineer with extensive business experience. They proposed a course that would teach the new product development process by simulating it in class. Student teams would come up with ideas for new products, design and prototype a concept, develop a bill of materials and manufacturing plan, and prepare a financial analysis, a marketing strategy, and a business plan. Each team's final presentation for the course would be a briefing to a group of venture capitalists – appealing for funding for their new company. Each team was also expected to submit a disclosure document or provisional patent to the U.S. Patent and Trademark Office. I assumed responsibility for this course in 1998. Since then, the traditional course has continued to evolve, and it has been adapted to different audiences and contexts. There are now three versions of *Creativity and New Product Development*, but they all share common goals and objectives.

Class objectives

We have three general goals for this course: (1) to provide an overview of the basic processes in new product development in a competitive marketplace by simulating them in class, (2) to acquire the skills for successfully creating and developing a new product through hands-on, team-based projects, and (3) to become more creative individuals and more effective team members.

The topics covered in this class fall into four categories: technical skills, creative thinking, business strategies, and people skills. *Technical skills* focus on issues of product specification, concept selection, product architecture, modeling and documentation, bill

of materials, prototyping (virtual and physical), manufacturing, and production planning. *Thinking creatively* explores how to generate ideas; how to elaborate concepts and alternatives; what psychologists, artists, engineers, and scientists know about creativity; and how to develop and foster, or stifle and kill, creativity. *Business strategies* include assessing customer needs; project scheduling; financial analysis; protecting your ideas; marketing, advertising, selling; and entrepreneurship. *People skills* involve team dynamics and roles; negotiating styles and strategies; appealing to the customer; understanding individual differences and preferences; and how to present your ideas effectively.

The creative thinking skills are often neglected in texts on product development. It is assumed that engineering students can generate solutions to problems. Unfortunately most of their education has focused on problems with known solutions and clear analytical procedures. Truly creative problem solving is rarely encouraged; the instructor wants to see the answer he or she already knows. In my classes, students find problems for which there are many possible approaches, and no clear best answer. The initial stage of the product development process is finding a good problem; the second stage is generating a wide range of possible approaches to solving it.

Class Format

In a typical class, the first week is devoted to generating ideas for projects. This is done in a brainstorming format: students suggest problems or needs that new products might be designed to meet. A complete list of all ideas is maintained during class, and distributed to all students after class. New ideas are added as students suggest them and the list is kept updated. By the second week, each student has chosen several ideas they would like to pursue. Any student with a strong interest in a particular idea can solicit team members for that project. By the end of this class, we have established a set of topics and preliminary teams. The topics are problems to be solved, not preconceived solutions.

Each team must then develop a Mission Statement and Project Schedule (a Gantt chart). During the semester, each team develops a series of design concepts to solve their problem, generates many alternatives, assesses customer needs (often using surveys and/or observational techniques), selects a final design, builds a prototype, generates a bill of materials and manufacturing plan, conducts a financial analysis, analyzes the competition, formulates a business plan and marketing strategy, conducts patent searches and prepares a patent application, and makes several formal presentations about their product.

This is not a lecture class. We have some lecture/discussion sessions and guest speakers on patents, intellectual property, and venture capital. But, most class periods are devoted to team interactions - with the professors observing, facilitating, and occasionally advising. We assign readings on new product development[1, 2] and entrepreneurship[3, 4, 5], and utilize web resources on creativity, invention and design, modeling and prototyping, patents, and entrepreneurship.

Three contexts for this class

For several years, we offered *Creativity and New Product Development* as a one-semester elective course for undergraduate students. We attracted mostly engineering students, but also an occasional student from the College of Arts and Sciences or School of Commerce. Typically fewer than 20 students were enrolled in any given semester, so the logistics of monitoring and managing the teams was relatively easy. One class each week was reserved for team meetings and the other was spent on lecture/discussion focused on particular topics or readings.

In 1999, we started offering a graduate version of *Creativity and New Product Development* in the distance learning mode. The initial offering of the class in this format had 33 students at 8 sites in Virginia and Pennsylvania. On-site, we had a mix of undergraduates and graduate students; all off-site students were graduate students with full time jobs. *Creativity and New Product Development* was also offered in the distance learning mode in 2002 and 2004; and will be offered again during the 2007-2008 academic year.

In 2002 we introduced a two-semester senior design option devoted to the design and implementation of engineering teaching kits (ETKs), and have continued to offer this version every year since. This project resulted from grants from the Payne Family Foundation and the National Science Foundation through their Bridges to Engineering Education program. In this course, teams of students developed instructional materials for use in middle school science and math classes. These ETKs have been described in detail elsewhere. [6 - 9]

Developing an ETK is a design project with all the usual stages: problem specification, objectives, customer needs, constraints, standards and regulations, concept selection, testing, revision, packaging, and documentation. The customers are middle school teachers and students. The objectives include teaching topics in science and mathematics with engineering applications, and introducing the engineering design approach to problem solving. Each ETK must address state and national educational standards, and must fit into the curriculum for the schools and grade levels. Every ETK includes a design competition – teams of middle school students must design and build a machine, vehicle, or structure that satisfies design constraints and meets a defined objective. The University of Virginia students must anticipate all the materials requirements, construction details, and potential problems and trouble spots. After teaching their ETK in a local middle school, our students document their experiences and refine their product.

This year, the *Creativity and New Product Development* class is a mixed implementation: the first semester was devoted to designing ETKs, and the second includes developing a new product idea from initial concept to prototype to business plan. Thus, the senior design class now has two distinct missions, and incorporates all the elements of the earlier versions of this course.

Table 1: Enrollments and number of teams in *Creativity and New Product Development*

Year	Number of students	Number of teams	Class format
1999	**33**	**7**	**Distance**
2000	**16**	**4**	**Traditional**
2002	**24**	**6**	**Distance**
2002/2003	**30**	**6**	**ETK**
2003/2004	**28/37**	**7**	**ETK**
2004	**41**	**8**	**Distance**
2004/2005	**30/36**	**7**	**ETK**
2005/2006	**37/33**	**6**	**ETK**
2006/2007	**38/36**	**6**	**Mixed**

Distance learning

Distance learning is now a critical component of the educational delivery system for many schools. At the University of Virginia, we have offered distance-learning courses since 1983 through our Cooperative Graduate Engineering Program. These courses are offered in the evenings to accommodate the working students. *Creativity and New Product Development* has now been offered three times in the distance learning mode. Each time the technology was different, and in some sense these seemed like three different courses. For many traditional lecture classes, this type of distance-learning environment is fine. For a hands-on, team–based and project-oriented course, the distance-learning environment is challenging.

In the Distance Learning situation, we must deal initially with classroom logistics and differing expectations among the students. This is a different kind of educational environment and is new to many of the students. The studio arrangement separates the students from the professor, and the fact that each class is broadcast and recorded intimidates some students. Our system now has two-way audio and video, so interaction between sites is possible. But, the professor must encourage the students to get them to actively participate in this environment.

Logistical issues include how to form teams and how large those teams should be. Prior to the start of the first semester teaching in the Distance Learning environment, I had made the decision to have at least one offsite member on every team. Further, I felt that each team should have 5 or 6 members. When we actually tried to compose the teams, these rules had to bend.

The next logistical issue involved generating ideas, and compiling a list of possible topics. We brainstorm during class, but many good ideas come in after class by e-mail. We typically distribute lists with over 60 possible projects for the teams to select from. I had originally planned to let teams form around topics – as we usually do in the

traditional version of this course. But this proved awkward, so we assembled the teams first and then allowed to them to select the topics they wished to pursue. We created teams to reflect diverse expertise and geographic dispersion. Each team had both on- and off-site members. In later offerings, we permitted a few teams with all members at a single location.

Titles of the projects completed in the distance learning version of this class are listed in Table 2.

Table 2: Projects in Distance Learning Classes

1999	2002	2004
Adapt – an - Organizer for Cabinets	Walker for elderly	Adams Photovoltaic Cell
Space Saver: 2000 Bike Rack	The Collegiate: Reading pillow/ bed rest	Keyless entry system
Ambulatory Peritoneal Dialysis Device	EZZZ Wake: a system for waking one person without bothering another	Tripod/ walking stick
Quick Check: Tire Pressure Sensors	The Drencher: a water balloon launcher	Ergonomic mouse
Teacher's Pet: a pet training device	EZ Screw: a screw driver guide	Firefighters' face shield
Item-Miser: Dorm Room Organizer	Smart grocery carrier/ ergonomic hand basket	Home irrigation system
One Step Pressure Check		Portable water purifier
		Bag Buddy Transport System for multiple packages

I have now taught the on-grounds traditional version of this course three times, the year-long ETK version four times, and the Distance Learning version three times.

Assessments

When dealing with project-based courses, I monitor the class dynamics closely. The students complete a first day survey (who are you and what do you expect to get out of this course?); midterm evaluations (how are things going?); a series of team ratings (how is the team working and what are you accomplishing?); and a last day survey (did you get what you wanted from this class?). We also obtain the usual formal course evaluations.

The students report generally high levels of satisfaction with the course and its content. They feel they got what they wanted from the class, and that we covered the material well. The only consistent complaints come from a few graduate students and most of the undergraduate students in the distance learning classes who don't like that format and

evening class time. Here also the off-site students expressed some dissatisfaction with the on-site students; they felt that the undergraduates weren't serious enough about their duties and deadlines, and that the graduate students were too concerned with theory and analysis, and not focused on practical issues.

Virtual teams can function effectively, but they require different strategies for success than collocated teams. Virtual teams need to plan better and coordinate their efforts. They must effectively divide their labor, and all members must come through for the team. Classic project management techniques work especially well in the distance learning environment. Collocated teams can put in intense last minute efforts (the weekend before each critical deadline). But distributed teams need to be far more disciplined.

Distance learning emphasizes the division between content and teaching style; the instructor feels there is so much to cover and wants to lecture. But the real benefit of this type of course comes when the instructor gets out of the way and lets the students work on their projects. The interaction of the team members is the crucial factor in the team's success. While this kind of interaction is natural in the traditional classroom, it must be nurtured in the electronic environment.

In the spring of 2002, the distance learning course was restructured and tailored to a new delivery system. Lectures and demonstrations were available asynchronously via streaming video on the Internet. Class met formally only one day each week, but students were expected to have viewed the on-line lecture prior to each meeting. Class time was devoted for team interaction and group activities. Additional facilities were available for video-conferencing, so teams could arrange meetings outside the class period. Ironically, the 2002 on-line course was the best I ever taught. It was particularly dynamic and exciting, despite the limited class time and pre-recorded lectures. The particular group of students was dynamic and involved, and every team wanted to excel. The competition was intense, and all students were deeply involved in their product. Most students traveled to Charlottesville to participate the final presentations.

Mixed mode version of *Creativity and New Product Development*

This year the senior design option includes both developing ETKs and generating new products. Our department's design review committee issued new guidelines for what qualified as a capstone design option. The traditional and distance learning versions of *Creativity and New Product Development* satisfied these guidelines. The ETK version of the class was adjusted to incorporate the missing elements by modifying the coverage in the second semester. These elements included CAD modeling and more engineering analysis.

In addition to input from our faculty, I regularly seek the opinions of my students on how the course is going and what they would like to us to cover. This year at the end of the first semester, I asked my students what they most wanted to learn from the second part of the course. The results appear in Table 3.

Table 3: Results of polling students on what they want to learn in our course

What you said you want to learn (accomplish) in this class?
Intellectual property/ patents (36)
How to get a patent? Understanding the patent process
What is patentable?
How to get rights to your own ideas (even when you work for a company)? Protecting your ideas
How to get companies to pay attention to your ideas (when you do not work for them)
Jobs related to patents and IP
Creativity (17)
More practice coming up with ideas
How to get novel ideas
How to solve problems innovatively
How to start a business (12)
How to write a business plan
How things work in the business world
Forms (types) of businesses
How to fund a business (11), raising funds
Presenting and marketing your ideas
Stages in the product development process (12)
Design process
How to innovate
How to do product design!
Team Dynamics/leadership (7)

We typically spend considerable time on creativity and teaming. The coverage of patents and intellectual property has increased each year; partly because we bring in outside speakers, including John Calvert of the USPTO on the U.S. patent system, Rodger Flagg of ExpressSearch, Inc. on Patent Search Strategies, Jack Hicks of Womble, Carlyle, Sandridge, and Rice, PLLC on Protecting Intellectual Property (including trade secrets), and Evan Edwards of Intellijject, Inc. on the adventure of starting your own business. Evan has a particularly energizing effect on the students because he started his journey in our class, and now has several patents and has formed his own company. He obtained funding from the NCIIA, and participated in the March Madness of the Mind at the Smithsonian Institution in Washington, D.C. He also entered the Darden Graduate School Business Plan competition, and was one of the finalists. He received funding and gained access to the Darden incubator facility. Evan is a powerful role model for our current students.

Moving forward - the next iteration of the distance learning experience

In the 2002 offering of the distance learning class, we were aware of the significant advances in collaborative technologies that had been made in a relatively short time. Students could interact electronically, and share documents, models, and visualizations.

Prototyping could be done at one site, with input from team members at many locations. This was the first class where truly virtual teams functioned as effectively as collocated teams in the traditional version of the class.

This fall, *Creativity and New Product Development* will again be offered as a graduate distance learning course. We will bring several new communication tools to this environment to allow teams to collaborate even more effectively outside of class. We will also work with a media design consultant to optimize the classroom experience for the students.

We will revise our logistics and teaming strategies. Although there are advantages to having teams as diverse as possible, but we have to make sure all team members are subject to the same rules. Some industries have restrictions on their employees that make it difficult to work with students at other sites. Our biggest problem to date occurred when one of our teams developed a very good idea, and the company employing one of the students decided they owned it. The student who came up with the original concept did not work for that company. This resulted in legal hassling and the breakdown of team morale. By the time the issues were resolved, the deadline for filing a patent application had passed. The team member who originated the idea is still pursuing it – without the benefit of a patent, and the company that caused the problem has lost interest. As a result of this experience, we will be much more explicit about the intellectual property issues associated with this type of class.

The motivation for entrepreneurship is greatest among the undergraduates. Most graduate students have become far too analytical and critical; building a finite element model is more appealing than creating a working prototype. They have also already made a major career decision. They are committed to doing research – usually academically oriented research. The folks working in industry are more receptive to entrepreneurship than graduate students, but they are often limited by the demands and restrictions of their jobs.

Moving forward – bring entrepreneurship into senior design

Our capstone design course has also continued to evolve. As seen in Table 3, our seniors want to learn to be entrepreneurs, and they recognize the need for business and financial skills. They are aware that the career paths of previous generations of engineers are no longer as available and that their futures will depend on their ability to be innovative and entrepreneurial.

We are striving to emphasize entrepreneurship even more in all these courses, and to provide students help in acquiring the resources they need to pursue their ideas. We draw upon the availability of faculty from business and commerce, and encourage our students to take courses in those schools. In addition, we now offer a business minor at our engineering school. We share a commitment to innovation and entrepreneurship with colleagues at many other schools, and hope for even greater emphasis in the engineering curriculum to help meet the challenges of the 21st Century.

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