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The Evolution of a Course on Creativity and New Product Development

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The evolution of a course on Creativity and New Product Development

Abstract

Creativity and New Product Development is a two semester senior design course for Mechanical Engineering students at the University of Virginia. Design thinking is fundamental to all stages of this course. It emphasizes creative thinking and stimulates the students to generate diverse solutions to problems. Students are required to work in teams developing new product ideas. Each team carries their idea through to a working prototype, and manufacturing and business plans. They also submit a proposal for funding and a draft patent application. In its current form, the class project is usually the basis for the senior thesis.

For this paper, we reviewed the teams and projects from the last ten years and identified those we felt were clear successes and clear failures. Most teams and projects fell in between; they were acceptable but not great. Our focus is to review what worked and what did not, and identify lessons learned for future course offerings.

Background

Since 1992, we have taught courses on innovation and entrepreneurship in the School of Engineering and Applied Science at the University of Virginia. Our first course *Invention and Design* [2, 8] was open to students from other schools at UVA as well as engineering students. It involved truly multidisciplinary teams where various engineering majors worked with students from psychology, music, mathematics, or architecture. Teams of students addressed three problems (1) they reinvented the telephone using the technologies available in the time of Bell and his competitors, (2) they had to design and prototype a new consumer product, and (3) they had to design a system to solve and environmental or social problem. For project 1, students had to study the writings and patents of Bell, Grey, and Edison. For the consumer product, we emphasized the importance of human factors and required the students to study the work of Don Norman.[6, 7] The development of this course was funded by the National Science Foundation and FIPSE.

The National Inventors and Innovators Alliance (NCIIA) had been founded in 1995, and we have participated in most of their annual conferences. Several teams from Invention and Design submitted e-team proposals, and some were funded. The most important consequence of the conference was learning what other schools were doing and meeting the key faculty working on engineering entrepreneurship; Larry Carlson and Jackie Sullivan at the University of Colorado[1], Burt Swersey at RPI, Tina Seelig and Tom Byers at Stanford, John Ochs at Lehigh, Elizabeth Kisenwether at Penn State, and Dani Raviv at Florida Atlantic, and many others. We incorporated ideas from these programs into our own. The support and advice of Phil Weilerstein also shaped our ideas on innovation and entrepreneurship.

Creativity and New Product Development was initially a third year one-semester course open to any engineering student. It was co-taught by two mechanical engineering professors and an entrepreneur who invented toys and surgical instruments. One of the professors, Dave Lewis holds 15 patents and has his own company. The entrepreneur, Henry Bolanos, has 120 patents, has founded several companies, and taught at Yale and the University of Auckland (New Zealand) as well as UVA. The real world perspective of these two colleagues enriched the course and encouraged the students' entrepreneurial ventures.

A distance learning version of Cr&NPD has been offered twice. It was targeted at graduate students from industry as well as students on – grounds at UVA. Undergraduates were also permitted to enroll with the instructor's permission. The logistics of teaching this material in the distance learning environment proved challenging. The technology was television based (with two-way communication). We assembled four person teams so that two members of each team were UVA students and two were from industry. Team meetings were mostly virtual, but some teams arranged regular face to face meetings. The students were satisfied with the delivery mode for the classes. But with current internet technology, this course could be vastly improved. The teams developed some great product ideas, and the students reported learning a great deal. There were a few problems with intellectual property issues for students from certain industries. Their companies wanted ownership of ideas from the teams their employees worked with. If we offer this course in the distance or on-line environment again, these IP issues will be dealt with in advance.

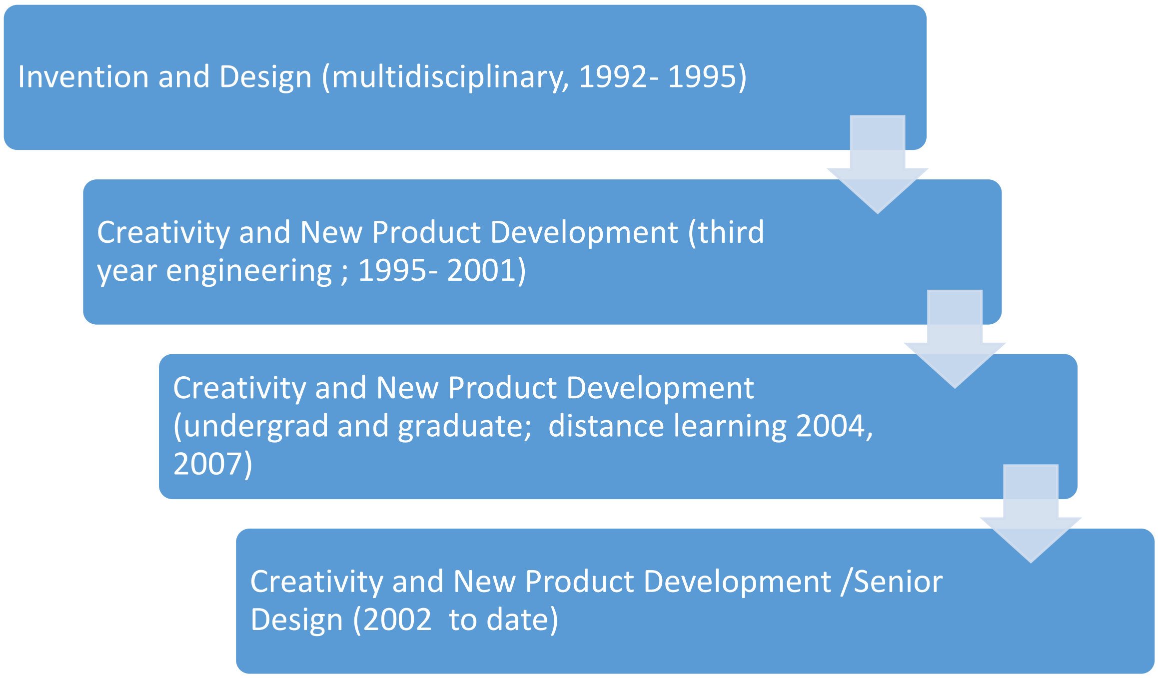

Figure 1: History of Creativity and New Product Development

In 2002, we started offering this course as a senior design option for Mechanical Engineers. The several incarnations of this course are shown in Figure 1. All versions of the course required students to work in teams developing new product ideas. Each team carries their idea through to a working prototype, and manufacturing and business plans. They also submit a proposal for funding and a draft patent application. In its current form, the class project is usually also the basis for students' senior thesis.

Structure and Content of the current course

C&NPD is now a two semester senior design course open only to Mechanical Engineering student. Students are expected to enroll for both semesters. This class covers the engineering design process by engaging teams of students in design activities that results in useful and novel products. We complete all stages of the typical product design process in this class, and perform the activities required by each stage. We introduce the concepts of intellectual property and its protection through patents, copyrights, trademarks, and trade secrets, and the technical tools of modern engineering practice, including solids modeling and rapid prototyping. Each team produces a working prototype of their product idea, identify the claims for a patent, develop a business plan for its eventual commercialization, and write a proposal for external funding.

We seek to learn the design process by actually engaging in design activity that results in useful and novel products: (a) ***Consumer products***. Using the skills and knowledge gained from their undergraduate education, teams of students identify a "real life" problem to be solved, and design a product to solve it; and/or (b) ***Instructional materials*** for introducing engineering concepts and the engineering design process to middle school students. These Engineering Teaching Kits (ETKs) are developed, tested, improved, and then distributed to middle schools for use in their existing science and math courses.

The course also covers the philosophy and techniques for effective participation on teams; ergonomics, human factors and user focused design; creativity techniques and practices, marketing, advertising and sales, and negotiation and presentation skills. We bring in outside speakers to describe their entrepreneurial journeys or to address issues related to intellectual property (patents, trademarks, and trade secrets). We also incorporate Case Studies to emphasize the decisions entrepreneurs face and the complexities of IP issues.

The major changes over the life of these courses are (1) we spend several weeks at the start of the class studying what is known about creativity (studying writings by artists, writers, psychologists and engineers) and doing exercises aimed at enhancing creativity[9], (2) we examine the literature on teams and team dynamics, and determine what works and what causes teams to fail; and (3) we spend much more time on intellectual property. We have three guest speakers devoted to IP issues – one from the U.S. Patent Office, one from our school's IP office, and a Patent Lawyer who is also a Mechanical Engineer.

Readings for the class include Ulrich and Eppinger[10] and Kelley and Littman[3] as well as articles from Wired, Fast Company, and Inc. We also link to TED talks and YouTube videos by Dean Kamen, Burt Rutan, Dave Kelley, Don Norman, Tina Seelig, Randy Pausch, and Steve Jobs.

Success or failure?

Over the years we have had notable successes and a few failures. This paper will review some course projects and teams from the last decade, and discuss what worked and what did not. We will also address the bottlenecks that prevent product ideas from being fully realized.

GOOD TEAMS: Some exemplary projects and teams

Three of my best projects resulted from a single student who took this course several times. Evan came into *Invention and Design* with an idea too good to share with the class – a credit card sized system for delivering epinephrine to patients with severe allergies. If he could carry it through, it would save lives and form the basis for a company that could improve health care is many ways. We told Evan we would work with him to develop his product outside of the class. He agreed and we ended up working with him for several years. As an undergraduate student, he was awarded his first patent, developed a workable prototype of his idea, entered a business plan competition and won some funding and space, and formed the basis for his company. His product and company are a great success and his story is told in Klinger et al.[4, 5] Evan regularly visits my Cr&NPD class and shares his story.

However, that product is not the only story. In other iterations of this course, Evan led teams that came up with two additional viable products (although they have not pursued either). CheckMate was a wireless communication system to pass messages between waiters and customers at a restaurant. He also led a team that developed an improved walker for elderly patients in a nursing home. To develop their walker design, they spoke to all the patients in a local nursing home, and incorporated those features they most desired. Thus Evan developed three product ideas in his time at UVA. A key element in Evan's success is his ability to notice problems and situations that need solutions, and the confidence that he can solve them.

1. *Passion; personal commitment*

Evan had a strong personal external motivation for developing his initial product the EpiPen; both he and his twin brother suffer from extensive and severe allergies. Another team in my class developed a potable kidney dialysis system because one member's brother needed it. Personal experience and need can make a product a mission!

2. *Innovation as play*

Another student, Joe, also succeeded with multiple products. In the first semester of my course, his team developed an ETK on the physics of sailing and sail design *Against the Wind*. Midway through the second semester, his team came to me to report that the product they had been designing had just been patented by someone else. Since I knew how much work they has already put into their idea, I said not to worry. I would consider it acceptable that they had developed a patentable idea, but were beat to the USPTO.

The team members had other ideas. I saw them meeting in the evenings in the student lounge. They eventually brought me another idea – a walker for patents with balance problems. The walker incorporated sensors to detect instability and a braking system. The team had a working prototype by the end of the term. Joe's team considered their first product a failure, but not a defeat! They put in the effort to produce a new product in a short time. They also considered prototyping as play in the tradition of IDEO.

3. *Truly divergent thinking*

Last year we had two great teams - one was concerned with the prevalence of concussions among football players and chose to redesign the football helmet. The team had four members and, after assessing the state of the art in helmet design, decided that each member had to come up with two potential redesigns independently. When they got back together, they had eight viable designs to consider. And all were truly unique. The team assessed all eight concepts and made a prototype of their preferred alternative. We encourage all our teams to engage in this level of divergent thinking, but most are not as successful as these students.

4. *External clients and deadlines*

Our first successful ETK was developed in 2002-2003. *Under Pressure* concerns the design of submersible vehicles. Middle school students learned about buoyancy (and neutral buoyancy), propulsion, and drag. The design challenge was to build a submarine out of a drink bottle. The vehicle had to be neutrally buoyant when submerged in a tank of water, and able to propel itself from one end of the tank to the other.

This team involved five women and one man, with a female faculty advisor and middle school teacher. The team experienced problems for most of the semester, and did not appear to be making much progress. There were questions and tension related to who was in charge, and what the team should be doing. Then the teacher agreed to have the team bring its ETK into her classroom – *in two weeks!* Suddenly the team gelled and work got done. A leader emerged and she became the spokesperson for the team. The team's lack of focus vanished when the (externally defined) deadline approached. They took their ETK into the classroom and performed very well. They were even featured on a local news show.

5. *Women as leaders and collaborators*

One other unique team arose in arose in a very large class. There were 40 students – eight were women. In the first meeting of the class I outlined my plans for composing teams and selecting projects. Each team would have four members and I would distribute the women so that there were two women on selected teams. Before the second meeting all eight women requested that they be allowed to be a team. Their leader Maria explained that they could work well together and would share the work. She said prior team projects made them unwilling to work with the males. They felt it was important for all of them to work together I reluctantly agreed but they did extremely well in the class. They tested their Engineering Teaching Kit in a local all-girls middle school.

BAD TEAMS: Some less than exemplary teams: How teams fail!

The good examples show how teams should operate, the bad examples reveal the flaws that lead to failure. However many of the successful teams faced these same challenges and overcame them.

1. *Team formation strategies*

The leftovers: this is a general category of student that appears almost every year. Teams form early in the semester based on topics the students select. There are always a few students that do not align themselves with teams. So make them get together. The results are usually not good; the last team to form is often the worst. These are folks who can't get their act together without external pressure.

Another problem with team formation is teams that form because they are all good friends, or fraternity brothers, or have strong ties outside of class. Teams of all guys often have problems getting things done.

2. *Distractions or diversions*

*Sanitation team***:** During a severe flu outbreak several years ago, a team was developing a coating to kill germs on door handles and surfaces. They decided to conduct experiments with materials and cultures to explore what prevented the spread of germs. They did some very good experiments but never got to the point of creating a product based on their findings. Sometimes teams get bogged down on details and don't get to the end point. Their project was good science but it did not become good engineering.

3. *Lack of skills needed to execute the project*

Make my drink proposed an automatic drink mixing system based on Mechatronic technology. Their elaborate idea at the start of the course became progressively simpler throughout the term. At mid-year a key member dropped out and the team was lost. They actually had to hire their former teammate to be able to complete their project.

There is a more general problem here; students often underestimate their technological sophistication and/or the complexity of the task they undertake. I discourage projects that require computer programming – most are unsuccessful. The only really great programming project took twice as long as planned; the student had to spend the summer after the class finishing it.

The Lone Wolf = one person teams

Occasionally, students come into the class with an idea they wish to develop on their own. They are concerned about sharing their intellectual property with other students. Usually we will encourage them to pursue their project outside of class, and work with a team in class on another idea.

Assessments

Performance in this class is assessed through a series of individual assignments as well as the team projects. There are about ten individual assignments, half a dozen team presentations, and two major reports. Most students complete all individual assignments satisfactorily. There is substantial variability in the team reports. Each year there are 2 or 3 exceptional papers; the rest are okay, but not exciting. And occasionally there are teams who just fall apart.

We have developed a set of surveys students complete throughout the year. The *First Day Survey* elicits basic data about the students and asks why they are taking this class; the *creativity/intelligence survey* assesses their beliefs about these topics and elicits a self-rating on each attribute; the *team experiences survey* asks about their good and bad teams experiences; after teams have been working together for most of the semester, they fill in a *team performance survey*, and we also conduct an *end-of course survey*. The results of most of these surveys are discussed in class, and they inform the direction and content of each class. Sometimes, these surveys identify problems within teams, and lead to corrective action. A consistent problem is that, during the class, teams report that they are functioning well and that all members are participating. But on the end of course survey, individual students complain about the lack of contributions from other students.

Creativity and New Product Development has consistently been the most popular senior design course for Mechanical Engineers, and has attracted more female and minority students than other MAE Design courses.

Observations and conclusions

- Exceptional teams view their project as a mission, not just an assignment.
- Excellence often results from a strong leader. The leader is usually the person who comes up with the idea, and is passionate about it. Sometimes other students just follow along, rather than developing and promoting their own ideas.
- Good teams tend to have a high level of enthusiasm, and have fun when they are together.
- Four person teams are best; five is okay; three is too few! With five members if one drops out or drops the ball, the team can still function. However, the six and eight person teams described above performed exceptionally well.
- Teams with women as members tend to perform better than all-male teams, especially if a woman is the leader. All female teams typically do well.
- Teams tend to stay together from one semester to the next – even if they are dysfunctional
- Teams that do well on one project tend to do well on both.
- Good teams make their own rules, and sometimes violate mine.
- External clients help focus a team, and increase its motivation. When a student brings a real-world problem to the class, they can usually form a functional team.
- My assessments of ideas are not always correct: after cell phones with cameras became popular, one of my students (working alone) designed and prototyped a selfie stick. I discouraged him; I thought it was a silly idea. I hope he followed through on his own. I now own a selfie stick.

Final Reflections

Our fourth year students arrive at their capstone course after two years devoid of design experience. They have taken a series of classes where there are well-defined answers to constrained problems. The right answer is the one the professor wants. They are frustrated that I do not tell them what to work on, or how to approach whatever problem they select. Some students are looking for the easiest way to meet the course requirements. They want to pursue simple ideas and tend to focus on problems with obvious solutions. This results in premature closure, finding one idea and sticking with it even when it is not very novel or unique.

Even with the resources of the Internet and World Wide Web, many students' research skills are quite limited. Most projects initially suffer from insufficient background research. Often several iterations a report are necessary to achieve acceptable levels of completeness and coherence.

Time management is a recurrent issue. Teams have to learn to do real work when they are together. They often fail to take advantage of all the time they have – brief periods before, during or after class, and even scheduled meetings outside of class

Teams often hide their problems until after the semester is over. On team surveys during the semester, they report that everything is fine. But in their end of course reviews, I learn about the uncommitted or delinquent members; those who miss meetings and fail to do the work they agreed to complete. Some students report an uneven balance of effort within their team. This is a problem of self-management within the team. I tell teams that they are responsible for their progress and team dynamics, and I will interfere only if truly necessary.

How intrusive should I (as the instructor) be? In earlier course offerings, this was not a problem. The commitment and enthusiasm of the students was wonderful. Indeed in one class the students informed me that I should get out of the way and let them get their work done. However recent classes (the last four years) seem to require more direction and control. The students need better scaffolding; with more frequent and tighter deadlines. They display bursts of activity as deadlines approach; but activity lags between milestones. Another problem is a lack of consistent documentation –they do not write everything down as they are doing them. Some teams lose things they have done, and have to recreate them from memory for their final reports. So future classes will have more stringent milestones, deadlines, and required documentation.

Changing the placement of the course within the curriculum would be desirable. Cr&NPD would be better as a second semester third year course, followed up in the first semester of the fourth year. Then students would have the opportunity to continue their work over the summer and into their senior year. This would increase their chance of getting external funding and actually carrying their product through to commercialization.

In some sense *this class is a victim of its own success*. In recent years the enrollment has grown. So there are more teams to work with. Originally we limited enrollment to about 24 students. Now classes of 36 to 48 are not uncommon. This creates a variety of logistical problems. Monitoring the teams is difficult and problems are easier to hide. Also the initial versions of the course were technical electives; they did not satisfy major capstone degree requirement. Every student was in the class because they were really interested in the material. Now I have students who enroll only to meet their senior design requirement.

Despite the problems and frustrations, I enjoy teaching this course and consider it one of the most important experiences our students have. Most seem to agree. The great projects make it all worthwhile, and the good ones are fine too.

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