

## **AC 2010-426: EARLY EXPOSURE TO ENGINEERING INNOVATION AND ENTREPRENEURSHIP**

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# Early Exposure to Engineering Innovation and Entrepreneurship

## Abstract

Innovation and entrepreneurship are key components of the skill set that engineering graduates entering the modern competitive and global workplace must possess. Here we describe a new course in Engineering Innovation and Entrepreneurship, intended for freshmen and sophomores. The premise was that the most significant impact of the course would be to present it early in the student's learning experience. The course was developed with funding from the Kern Family Foundation's KEEN program. The goal of the course is twofold: First, we seek to introduce students to the broader context of engineering that installs a mindset accepting commercialization as a natural part of the introduction of new technologies. Secondly, we seek to provide the students with a "toolbox" of skills to understand the business world and to assess the commercial context and viability of new technologies.

## 1.0 Introduction

It is agreed by those pondering the future of engineering education<sup>1-4</sup> that innovation and entrepreneurship (I & E) must be part of the experience that graduates entering the modern competitive and global workplace must possess. At our institution, and many other educational institutions, engineering students interested in innovation and entrepreneurship have several opportunities to pursue their interests. Usually only a small fraction of the engineering graduates take advantage of these opportunities. In spite of that we believe that all or most engineering students would benefit from being exposed to innovation and entrepreneurship early in their studies and that the importance of I & E must be reinforced throughout the curriculum.

Here we describe a first-year course at the Worcester Polytechnic Institute, intended to introduce engineering students to the importance of innovation and entrepreneurship for the economy and to ignite their interest by raising their awareness of the issues and solutions that surround the process. The course consists of an introduction to the role of new initiatives, examples of successful execution of new innovations and detailed information about how to develop new ideas, protect them and develop the concepts into new enterprises, units, or product lines. The goal is to create a perspective for innovation and entrepreneurship in all of our engineering students and to serve as the first step in a more comprehensive program. First, we seek to introduce students to the broader context of engineering, installing a mindset that accepts commercialization as a natural part of the development and introduction of new technologies and that those new technologies often require new business models. Secondly, we provide the students with a "toolbox" of skills to understand the business world and to assess the commercial context and viability of new technologies. The long term intention is to integrate I & E into the educational perspective of all students in their earlier years on campus

The course was developed with funding from the Kern Family Foundation as part of the KEEN program. The proposal was for a two-year pilot program and included the creation of new course entitled Innovation and Entrepreneurship (later identified as ETR 11XX) to be offered to

freshman to achieve the most impact on their education process. The elements of the proposal were:

- Two offerings of an introductory course on engineering innovation and entrepreneurship
- A review of best practices at other institutions, including other efforts supported under the KEEN program.
- A faculty workshop to enlist the perspectives of our colleagues.
- Development of a long term integration plan to extend these efforts campus wide
- Assessment of the courses and process

The course has now been offered twice and here we describe its structure and the student reaction to it, as well as the broader campus context.

## 2.0 Structure of the Course

The I & E course consists of lectures, discussions and a project. The course is a collaborative effort, taught by the PIs who come from the Department of Mechanical Engineering and the Department of Management. It is further built on the legacy teaching of the individual disciplines but represents a synergistic melding of the individual perspectives. This factor is an important element of the success of this project. The lectures are used to introduce various topics such as identifying customer needs, opportunity recognition, role of start-ups and venture capital, innovation, and intellectual property. The discussions focus on several Harvard Business School cases and text readings about technology ventures and technology entrepreneurs selected to be relevant to the course objectives. In the team project, which culminates in a report and a presentation, the students are challenged to look at a selected innovation opportunity and explore its value proposition, its commercial feasibility, the various risk factors, and the resources required. The class was divided into five separate groups, but all groups worked on the same overall problem. Additionally, excerpts from the writings of thought leaders on innovation, such as Carlson, Christensen, and Porter, were included. To give us more time for extended discussions, the class met twice a week, for two lecture hours each time. The syllabus for the fall of 2009 is shown in figure 1.

Our institution operates on a somewhat unusual academic calendar where each semester is split into two seven-week terms. Terms A and B are taught in the fall (September to December) and terms C and D are taught in the spring (January to April). During each academic term the students take three intensive courses, usually consisting of four lectures plus problem sessions as appropriate. In some cases laboratory sessions replace lectures. The course was designed to fit into one term.

The course was designed to contain the following elements:

**“Toolbox”:** To conduct meaningful discussions about the role of commercialization in innovation and how to identify and pursue entrepreneurial opportunities with the students it is necessary to introduce the basic functional elements of business fundamentals. We choose to do so by introducing a commercial “toolbox” early in the course that would enable the students to embrace the concepts presented in subsequent lectures. The elements of the “toolbox” were defined by classical business functional areas such as marketing, accounting, operations and

general management. The dilemma we faced was how to present materials that take a full course to topics in singular lectures. We accomplished that by a combination of lectures and informational utilization of B School case materials.

**Case Format:** Based on the experience of one of us in teaching Entrepreneurship in the Management Department, we decided to utilize Harvard Business School (HBS) cases instead of a textbook. We choose specific cases to represent each functional area (i.e. marketing) that was grounded in either Innovation or Technical challenge. In addition, selected text material from Curt Carlson’s book on Innovation<sup>5</sup> and Clayton Christensen’s book about Disruptive Change<sup>6</sup> were utilized. Each topic was presented by a focused lecture by one of us.

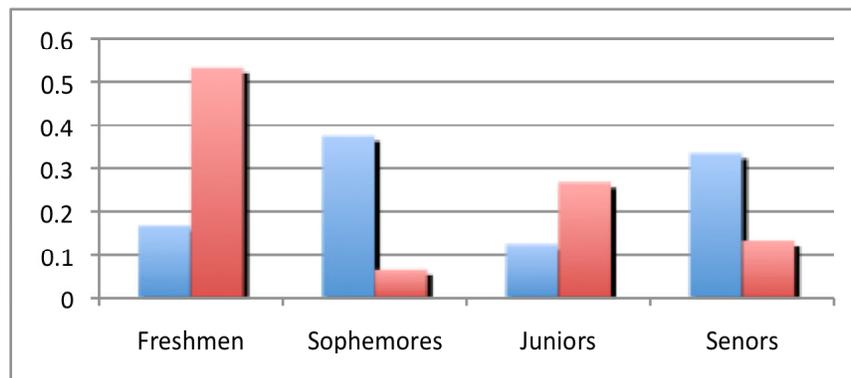
**Project:** An important element of the course was a class project that comprised a significant fraction of the grade. We used a common project topic and divided the class into teams of about five students each. The theme was to focus on the development of an Innovation Plan to solve a medical challenge of the application of a robotic approach solution to knee meniscus repair. This topic was felt to be sufficiently technical to engage the team without encountering the biomedical aspects of the problem. The teams worked together for four weeks, concluding with a presentation and a written report.

Date	Topic	Reading *
10/29	Introduction – Innovation and Entrepreneurship	
11/02	Pathways - Utilizing Existing Organizational Models	Marketing Myopia (HBS 4070L), Christensen -Chapter 6, pg 226-230
11/05	Markets and Opportunities – Looking outside Speaker: Professor Chick Kasouf	Apple, 2008
11/09	Pathways – the role of the Start-up Organization – Venture Capital	Linking Stgy. and Innovation: Materials Tech.y Corp. (HBS 9-696-092)
11/12	Quantifying the project – The numbers Project Introduction	Bootstrapping Finance: The Art of Start Ups (HBS 92601)
11/16	Operations, and Organizational Issues – Looking Inside- Limitations on Growth	3M – Optical Systems, Maintaining Corporate Entrepreneurship
11/19	Innovation, Feasibility Analysis, Commercialization / Introduction to NABC Project Definition	Carlson – Chap 2, 4, 9 Project Work
11/23	Disruptive change in the Disk Drive Industry	BIOCOM: From Generics to Mfg to Bio Innovation (HBS HKU657) Christensen – (Chap. 1, 9 & 10)
11/30	Sources of Innovation Outside speaker: David Weisburg, IDEO	Managing Innovation at Nypro (HBS 9-696-061)
12/03	Barriers to Innovation- ....and overcoming them Mechanical Excavation and Innovation Quiz 1	3M ESPE AG: IP in Dental Christensen – (Pg 69-72, 83-87)
12/07	An IP Perspective Technology Transfer	Outside speaker from our Tech Transfer Office
12/10	Project Review (Elevator Pitch)	Project work
12/14	Project Presentations	

**Figure 1.** The course syllabus for the second offering of the course in the fall of 2009.

**Outside Speakers:** To enlarge the coverage, to offer the students a broader perspective, and to help the students better grasp the various aspects of I & E, we brought in two outside speakers. The first outside speaker talked about his experience working on product design at IDEO and the many diverse considerations needed in coming up with marketable products. The other speaker was the person in charge of technology transfer at our institution who discussed the role of intellectual property in the innovation process.

The first offering of the course took place in the second half of the spring semester of 2009 (D Term). Although the original intent was to offer the course to first and second year students, concerns about enrollment led us to open it to all students, including seniors. Although enrollment was set at twenty students, we ended with a slightly larger number (twenty four), due to a relatively heavy demand for the course. For the second offering we decided to increase the enrollment to thirty students but limit it to first and second year students. In spite of our best intentions, we ended up accepting several juniors and a few seniors who had heard about the course from their peers and felt that it was just what they had been looking for. Figure 2 shows the demographic mix for both offerings of the course.



**Figure 2.** Student demographics for the first (blue) and second (red) offering of the course as a percentage of total enrollment.

The format described above, consisting of lectures on specific topics and extensive class discussions, worked very well and generated both enthusiasm and engagement. Similarly, the teams worked well together on their projects and produced a diverse set of solutions. Although all students enrolled in the course participated actively in class discussions, the more advanced students generally dominated in executing the project. Students enrolling in the course came from almost all engineering departments at the institution as well as a few from the Department of Management. The majority of the engineering students did, however, come from a newly established program in Robotics Engineering<sup>7</sup>, which requires one course in entrepreneurship. The present course satisfied that requirement.

As a project we elected to give all the student teams the same challenge. Given the general interest of the student body in the application of robotics and medical devices, we provided the students with a broad background on the importance of knee meniscus repair and asked them to come up with an innovation plan involving the use of robotics. We stressed that we were not looking for a detailed design of a device but for a plan to introduce a new solution. We wanted the students to come up with an idea and describe how they would realize it. In the first offering

of the course we did not communicate well to the students what exactly we were expecting and for the second offering we asked them to base their report and presentation on the NABC<sup>5</sup> approach where the Need, Approach, Benefits and Competition are explicitly addressed. Given the limited time and the limited background that the students had with the problem, we were not looking for a full-fledged business plan, but rather a first iteration of what might become a more substantial document. Although the student teams had only limited opportunities to improve their presentation by repeated iterations with their peers, we felt that the NABC methodology gave them a much-needed structure for their project and that it helped communicate exactly what we were looking for.

### 3.0 Assessment

Several tools were used to examine the success of the course, including how well students learn what is being taught, how well they liked the format, and what impact the course has on their attitude toward innovation and entrepreneurship.

#### 3.1 Statistics

The quantitative data collected consisted of:

- KEEN Assessment
- Institutional Course Evaluation
- Quiz Results and Project Grades

##### 3.1.1 KEEN assessment

The Kern Family Foundation provided an on-line assessment of the student’s attitudes about entrepreneurship that was administered at the beginning and end of the first offering of the course. During the second offering the survey was not available online and was administrated in a paper format.

A similar assessment was done for other KEEN supported courses taught during the 2008/2009 academic year at other institutions. While only about half the students in our course responded (a total of fourteen), over fourteen hundred student responded in total. The Kern Foundation examined the data and reported that compared to other institutions, our students generally done very well. A summary from the Kern Family Foundation is shown in figure 3.

		Tasks	WPI Performance	
			Compared to KEEN Group	Compared Internally
Innovation ESE		Create new ventures with new ideas.	Outperformed Group	Most Improvement
		Break into new markets and geographical territories.	Outperformed Group	Most Improvement
		Develop new methods of production, marketing, and management.	Outperformed Group	Most Improvement
Risk-Taking ESE		Create new products and services.	Outperformed Group	
		Take responsibility for ideas and decisions.	Average Performance	Least Improvement
		Make decisions under uncertainty and risk.	Outperformed Group	Most Improvement
		Take calculated risks.	Outperformed Group	
	Work under pressure and conflict.	Outperformed Group	Least Improvement	

**Figure 3.** Comparison of the results for the present course and the first offering of the course.

Selected questions from the second offering of the course are shown in figure 4, where the number of students expressing each confidence level is identified by two numbers. The first

number is from the beginning of the course and the second numbers is from the end. In most cases there is a marked (positive) change in their confidence in the various aspects of entrepreneurship. Although only a few sample questions are shown here, the same trend was seen for other questions, as the aggregated response for all questions (bottom line) shows.

I am	Not Confident	Somewhat Confident	Confident	Very Confident
1. Work under pressure and conflict	7/0	5/9	7/12	2/0
5. Set and attain profit goals	5/0	10/7	6/8	0/6
11. Manage time by setting goals	1/10	9/3	10/7	1/1
15. Perform financial analysis	0/0	7/10	14/9	0/2
All 21 questions	109/31	212/163	174/229	78/114

**Figure 4.** Four questions from the KEEN assessment tool and the total for all questions from the second offering of the course. The questionnaire has 21 questions total.

### 3.1.2 Institutional Course Evaluation

At the end of all courses at our institution, the students complete a formal course evaluation. The responses are anonymous and not reported back to the instructors until after grades have been assigned. In addition to evaluating various aspects of the course on a five-point scale, the students have the opportunity to provide written comments. The results for a few questions are reported in figure 5 for the first and the second offering of the course.

Overall the student opinions of the course are very high, although the second offering was generally received slightly better than the first, as perhaps is to be expected. The student comments generally were also very positive

#	Question	Spring	Fall
1.	Overall this course is excellent	4.0	4.5
2.	Overall the instructors teaching is excellent	4.1	4.7
3.	Textbook and/or assigned reading	3.8	4.4
12.	The instructor stimulated my interest in the subject matter	4.0	4.4

**Figure 5.** The results of student assessment of the course for both the first and the second offering.

### 3.1.3 Grades

The grading of the course consisted on several components: Homework (15%); Project presentation and report (35%); Quiz (30%) and class participation (20%).

Homework, due in every lecture challenged students to reflect on the reading for the upcoming class. The write-up was limited to one page and had to provide a synopsis of the material read and a few points for the class discussion of the material. The students initially had some difficulty with the concept, including limiting it to a page, but after the first weeks there was a noticeable improvement.

The Quiz, given near the end of the class before the project was due, consisted of two parts. Ten questions examined the students understanding of the various topics presented in the class and three questions asked the students to summarize what they learned, what recommendation they had for changes in the course, and how the course had changed their personal perception about Innovation and Entrepreneurship. Overall the students showed that they had grasped the main concepts presented. By examining the questions that they missed, we were however, able to identify a few topics where they did not do as well as we hoped. For the second offering of the course, we followed up with discussions of finances and venture capital, income statements, and the entrepreneurial mindset.

Both instructors graded the project reports and presentations, with additional input from two colleagues who were present for the presentations. The grading was based on a rubric given to the students as part of the project description, that included the quality of the value proposition, the commercial feasibility of the innovation, assessment of risk factors and resources needed.

Grade	First	Second
#A	61%	36%
#B	39%	64%
#C	0%	0%

**Figure 6.** The grade distribution for both offerings of the class.

The overall grades for the course were generally high, as is to be expected for an elective course. Figure 6 shows the grade distribution for both offering of the course. The grades are higher for the first offering, reflecting both the larger number of upperclassmen and possibly the smaller class size.

Figure 7 shows the grades for the second offering of the course, broken down by class year and while the juniors got more A's than B's and the opposite is true for the freshmen, the correlation is perhaps not as strong as one might have expected. We note that for the projects, where we assigned lower and upperclassmen to different teams to try to avoid the latter dominating the former, there was no clear correlation between project quality and class year either. We also note that the range of grades was larger for the second offering of the course than the first, perhaps due to the larger class size.

Class	A's	B's	C's
Freshmen	4	9	0
Sophomores	1	1	0
Juniors	4	2	0
Seniors	1	3	0

**Figure 7.** Grades from the second offering of the course.

### 3.2 Anecdotal evidence

In addition to quantitative data, we attempted to gather more informal input, both by asking the students for written comments as well as by interviewing them directly. A sample of student

comments is included in figure 8. The comments are taken from the second part of the Quiz, as described above.

**1. If you were to describe to another person three important elements you learned in the course, which would they be:**

“I have learned that innovation is not about the most advanced product, but the most DESIRED one. I have also learned that a well-planned innovation plan is a key to success. And finally, I learned that history provides an excellent example for the future.”

**3. Has this course changed your personal perception about the themes of Innovation and Entrepreneurship. If so, how:**

“It has. It has given me the tools—“new eyes”—with which I can analyze possible ventures. I learned how one can take the first steps into starting a successful company and how one can be sustained. I learned that it isn’t about who has the “best widget” but who has the best “customer value”—and that is a valuable lesson.”

“Most Certainly. I now see innovation as developing a product that customers will want, as opposed to developing the most advanced product. I see entrepreneurship as a much more structured, exciting thing than I did before.”

“I thought that business was dry and boring. It still is (facts and figures) but by studying here I found that the underlying trends more interesting and how business flow etc. Innovation is interesting.”

**Figure 8.** Selected student comments from the second part of the quiz, from the second offering of the course. The questions that we posed are in bold.

#### **4.0 Discussion**

Although the first offering of the course was successful and the second offering was oversubscribed, we did, nevertheless, adjust several aspects of the course based on what we learned the first time. Perhaps the main lesson was that admitting upper-class students into a course that was primarily intended for students in the early part of their educational experience made it much harder to target the message and to ensure equal participation by all students. For the second offering we therefore we ensured that freshmen and sophomores had the first opportunity to enroll in the course. Only after that did we open enrollment to accept a small number of upperclassmen who had heard about the course from their peers and argued strenuously for admission. To lessen the change that upper-class students dominated the discussions we divided the students into project teams by class-year. Although this ensured that all the team members had better opportunity to participate in the execution of the project, we have concluded that future offering of the course will be strictly restricted to first and second year students. The objective of the course is to instill an increased awareness of the issues of innovation and entrepreneurship early in their education process and admitting upperclassmen is obviously not consistent with this goal. Allowing senior students into the course for the first offerings were motivated by two concerns: The first was that early their education cycle the

students might not have a firm experiential basis for appreciating and contributing to the subject matter and by allowing a mix of some upperclassman this concern might be mitigated. The second issue was that as first offering, there might not be sufficient students enrolled to provide a substantive class experience. Neither concern turned out to be justified.

The definition of the project provided us with a significant challenge. Our goal was a project where the students developed a plan (an innovation plan) to introduce an innovation in a specific area. They had to address the customer needs, define an approach, discuss the benefits to the customer and to identify their competition. Although the students had to specify the approach in sufficient details to make it clear what they wanted to do, we explicitly did not want the project to be an exercise in product development. In the first offering of the course we found that the students spent significant time on data gathering and detailed design of their approaches. For the second offering we therefore gave the students more data and spent more effort to explain what the project is and what it is not. Perhaps one of the most challenging and remaining issues is the valuating the innovation component of the students work in both the classroom and on their projects. In a way, this is ironic in that this should be the most challenging aspect when the amount of the work in the field seems so significant.

The cases selected for the first offering of the course were well received. The cases were selected to represent an area of functional interest, have a technologically grounded topic and present an innovation challenge. Although the students found most of the cases interesting and they generated good discussions, in a few cases we decided that cases that we had selected for the first offering were not optimal and thus replaced them for the second offering. However, overall we felt that using HBS cases worked well.

## **5.0 Innovation and Entrepreneurship on Campus**

Like most universities, our institution is currently devoting considerable effort to increase the emphasis on innovation on campus, both among students and the faculty. The course described here is well aligned with this broader effort and the KEEN funded activities included two faculty workshops in addition to the two offerings of the course. The first faculty workshop, held in the fall of 2008, included over twenty faculty members and the second one was in the fall of 2009, with a slightly smaller number of participants but a more focused agenda. All participants expressed great enthusiasm and several of those who were invited but could not attend asked to be included in future discussions.

The introduction of the innovation and entrepreneurship course coincided with a rapid enrollment growth in a new BS degree program in Robotics Engineering<sup>7</sup>. This program, the first in the US, was introduced in 2007 and was designed to include many of the elements commonly believed to be important in engineering programs of the future. This includes a requirement that all students must take a course in entrepreneurship.

## **6.0 Conclusion**

Exposing all engineering students to I & E is going to be an important component of engineering education in the twenty-first century. Here we have described an experimental course designed to

explore what the content of such a course might be like. Although offered as an elective course, it drew students from a range of disciplines and thus gave us some indication of the needs of a diverse group of students. The course employed a format that is somewhat unusual in regular engineering courses, devoting significant time to class discussions. Nevertheless, the various assessments conducted suggest that overall the course was a success. Explaining to the students exactly we expect of them in the project is probably one of the major challenges we have encountered, possibly because of our own inability to articulate it well enough.

## Bibliography

1. *The Engineer of 2020: Visions of Engineering in the New Century*. National Academy of Engineering (2004). Available for free online reading at: <http://www.nap.edu/catalog/10999.html>
2. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. National Academy of Engineering (2004). Available for free online reading at: <http://fermat.nap.edu/catalog/11338.html>
3. J. J. Duderstadt. "Engineering for a Changing World. A Roadmap to the Future of Engineering Practice, Research, and Education," 2007. Available online at: [http://milproj.umm.umich.edu/publications/EngFlex\\_report/](http://milproj.umm.umich.edu/publications/EngFlex_report/)
4. G. Tryggvason and D. Apelian, "Re-Engineering Engineering Education for the Challenges of the 21<sup>st</sup> Century." Commentary in JOM: The Member Journal of TMS, October 2006. Reprinted in IEEE Engineering Management Review, 37(1), 2009, 38-43. Also translated into Chinese (China University Teaching, 12 (2008), 84-86.)
5. C. R. Carlson and W. W. Wilmot. *Innovation: The Five Disciplines for Creating What Customers Want*. Crown Business 2006
6. C. M. Christensen. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Harvard Business School Press, 1997.
7. M. J. Ciaraldi, E. C. Cobb, D. Cyganski, M. Gennert, M. Demetriou, F. Looft, W. R. Michalson, B. Miller, Y. Rong, Professor, L. E. Schachterle, K. Stafford, G. Tryggvason, J. D. Van de Ven. "The New Robotics Engineering BS Program at WPI." ASEE Annual Conference & Exposition, Pittsburg, PA, June 22-25, 2008.