AC 2003-22: BEYOND SOLUTION FIXATION: A SHORT COURSE ON ENGINEERING AND BUSINESS CONCEPTS

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Beyond Solution Fixation:
A Short Course on
Engineering and Business Concepts

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Abstract

While most graduating engineers have solid training in applying engineering principles to analysis, product design, testing and other technical duties, they are frequently not prepared to understand the nature and goals of the companies and ventures that employ them. Many studies have noted the disconnect in engineering curriculum between the assessment of customer needs as dictated by the marketplace and the engineering of products. In product design and development engineers are often quick to offer solutions without fully exploring the actual need and market for those solutions. Approaching a problem with this kind of "solution fixation" can limit an engineer's contributions in business environments. What business skills do engineers need to acquire and how does the engineering mindset influence an engineer's business savvy? Using funding from the Ford Motor Company; faculty from The University of Texas at Austin (UT) in the mechanical engineering department and graduate studies program and staff from the Faculty Innovation Center (FIC) are exploring answers to these questions by creating a curriculum for a short course on business skills for engineers.

This paper provides a look at the pilot short course's curriculum, strategies, and resources used to present and teach interdisciplinary concepts related to engineering and business. The following three components were used in the instructional process: teaching notes; a course-package; and interactive multimedia resources. Fundamental to this short course is the notion that business is about relationships and communication. Through exercises, students are encouraged to develop their questioning and listening skills to guide them in a range of business interactions. This short course endeavor complements a larger project within the mechanical engineering department focused on implementing project-based learning into the curriculum.

Introduction

Today's corporate leaders stress that while they are not necessarily looking for engineers to possess MBA's in marketing or finance, they are looking for new graduates to possess better "soft skills" (e.g., written and oral communications aptitude; marketing-related knowledge; and familiarity with business and financial matters). They note that these soft skills be emphasized, taught, and practiced in the undergraduate curriculum.[1] As students enter the multifaceted, interdisciplinary private sector, they are limited in advancement if their skill set is restricted only to their own discipline. An understanding of the processes and context of a workplace enables richer communications and more effective practice. Several authors, including Long, have discussed the impediments to enhancing the engineering curriculum with business and

management topics [2]. Long indicates that a major point of resistance to adding business based courses to the engineering curriculum is the ever expanding number of course hours required to complete a bachelor of science. Long brings up another problem that is often not addressed in the lack of qualified engineering professors to teach business issues from an engineering context. Farr and Merino discuss how engineering faculty attempt tend to model the environment in which they received their education at their teaching institutions, and how few engineering faculty have industry experience [3]. Grigg discusses the "skepticism and hostility" with which most academic engineers view entrepreneurs and entrepreneurship. He further notes that the specialized nature of the university in general does not nurture academics that are synthesizers[4]. The types of obstacles noted by these authors are real. Nevertheless, there is a clear message from industry and also implicit in ABET that the undergraduate learning experience for engineers must be modified to provide context for the theoretical knowledge. Business issues and the marketplace are a valid context for engineering.

Our Solution

Engineering students at UT Austin are benefiting from educational innovations[5]. Gains in cognitive science and the proliferation of instructional technology resources are resulting in better instructional practice and tools that promote student learning[6]. In particular, the department of mechanical engineering is implementing project-based learning across its curriculum in order to provide students with opportunities for practical applications of engineering ideas and concepts. "It became evident in the development of the project-based curriculum that one aspect of project-based learning that is not typically addressed in engineering curricula is the integration of engineering ideas into a larger framework"[7]. When engineers realize that the value of their designs is a function of market needs, they are better prepared to assimilate into commercial ventures.

The need for introducing business concepts to engineering students was therefore not in question. However, finding the best solution to meeting this need was a dilemma, particularly given the types of obstacles presented in the previous section. Adding additional courses into engineering students' demanding schedules would only overload them, and sending them to the business school to take classes might mean that their engineering expertise would not be integrated into the course objectives. It was determined that there may be value for the students to look at business concepts through the filter of their "build a better mousetrap" engineering perspective. There are several existing templates of engineering design based courses that have begun to add more rigorous economic and market analysis to the traditional engineering content. Carlson and Sullivan present details of a mechanical engineering design course, *Invention and Innovation*, at the University of Colorado which incorporates economic and market considerations into the overall design feasibility [8].   Unlike the University of Colorado course which is a full semester course, a decision was made to offer a three day short course during the semester break to students and to build a set of Web-based, supplementary resources for the students to access as needed. While it is felt that some of the modules and content developed for the short course can feed into semester long courses in design, engineering economics, and technical communications, the short course environment provides an environment to test which concepts can feed best into the existing courses.

Short Course Planning

In order to make sure the short course curriculum represented an in-depth look at marketplace variables, a multidisciplinary team was assembled to create the short course curriculum. This team consisted of a mechanical engineering faculty with experience in entrepreneurial endeavors; graduate students in mechanical engineering with interest in business concepts; a graduate studies faculty member with experience in communication techniques and tools; an instructional designer with experience in curriculum development and business consulting; and media developers with experience in Web-design and simulations.

Planning for the short course occurred during weekly meetings. The first item on the agenda was to discuss our audience. Would the curriculum be appropriate for those with actual business experience or would it appropriate for those who are still in engineering school? Would the curriculum be appropriate for someone who wants to work in a small business or for someone who wants to work in a large corporation? What current understanding of the marketplace would they need to begin this workshop? After much discussion, we decided that the audience for the pilot course would be upper-level engineering undergraduate students and graduate students who are interested in entrepreneurial opportunities. Once the prototype curriculum was created for our initial audience, we intend to adapt and modify the curriculum for a broader range of audiences.

Next, the team struggled with course objectives. Any good course planning begins with writing course objectives: why is this material being taught, and what should students be expected to know and demonstrate at the end? Course objectives perform three important functions by guiding the instructional process; providing a framework for evaluation and assessment; and guiding the learner[9]. However, developing course objectives and consensus based on these outcomes was not trivial. The instructional designer was able to coach the team in this process, and the team eventually arrived at the following course objectives:
- Identify and describe the function and properties of agents in a business process
- Select the correct tool for decision analysis from a product business toolkit
- Perform basic market research
- Pitch an idea
- Practice management of equals in group dynamics
- Evaluate product technical constraints and feasibility

Using these objectives as a guide, we then discussed how we would know if and when the students had achieved the objectives. Since the short course is not for credit, we had to find ways to assess student learning without grading. While active learning (learning where the student is doing and is involved) is becoming a current higher education mantra, we knew we really had to put that concept into practice. If the students aren't actively assessing their learning as they progress through the short course, it is highly unlikely that they could successfully attain the desired outcomes. We decided that student understanding would be measured by their ability to participate in the discussions and their ability to contribute to a team project.

Our next major development step was to look at existing resources and to find materials that were applicable. A plethora of materials on business and its processes are available, but what we needed were materials that went beyond the fundamentals and yet were basic enough for non-business majors. Merely presenting business theory would not encourage critical thinking, so we

needed a way to deepen and reinforce subject matter knowledge. A careful review of the case study approach to learning business concepts prompted us to incorporate case studies from the Harvard Business School into the curriculum. Case studies present a salient, real-world problem to which students can then apply their knowledge by analyzing the scenario and possibly suggesting a resolution. In choosing appropriate cases, there was an effort to focus on cases which involved significant product design and/or development issues.

But we also knew that teaching with case studies did not enable us to explore some of the "softer" aspects of business. We wanted to expose students to the business of communications and human interactions. It is relatively well known that communication skills are fundamental to success in business, and that in many respects the "business of business" is communicating with the players in the marketplace. Our experience suggested that engineers come to a situation with a solution in mind before weighing the actual needs involved. An essential aspect of the short course was to develop and provide a communication "toolkit" to guide the students as they questioned business processes and strategies.

We decided to use a single case study to provide a problem scenario and then for the students to work in teams to provide a solution to the case's needs. At question were how much business theory background would be useful and what sort of communication tools the students would find relevant. Our approach was to provide students with in-depth materials, exercises based on the case study, a template to guide their team activity, and plenty of opportunity for discussions.

Short Course Pilot

We reasoned that once students begin classes, it is highly unlikely they will have time to attend an evening or weekend short course during the normal semester. So we decided to offer a short course during the break before the beginning of the semester. We felt that students would sign up for this offering because they had an interest and were motivated to learn more, but we still took assurances to make this course highly interactive and productive. For the pilot, we were able to provide free lunches as an incentive. An announcement was sent out to faculty teaching senior-level design classes, and twelve students responded to our invitation.

The following three components were instrumental to the short course delivery: teaching notes; a course-package; and interactive multimedia resources. The teaching notes outline the course structure and agenda. The course package includes copies of the presentations, articles on business concepts and organizations, conceptual engineering and customer-defined methods, teamwork, and communication strategies. It also contains a process template to guide the students while working on their team assignment. The multimedia resources are still in development and will be discussed in another section of this paper.

Fundamental to this short course is the student's ability to practice the concepts they learn. Prior to their experiential activity in the short course, the students listened to talks on business processes and engineering design. They were introduced to the "idea to impact" cycle and the role engineers play in that process. Once the basics were presented, the case study problem was given. The case study was presented in an abbreviated form where only the initial scenario was detailed. The case study in question is called SweetWater[10]. SweetWater is the name of an

actual portable water purification system used by campers. The students were not told that the product actually exists, but were instead told a story of a camping trip where a group of friends took portable water filtration systems which did not meet their expectations. Students were told to begin thinking about the needs of the campers with respect to potable water. The students were given these guiding questions:

- What would you do for campers going on a trip like the one described?
- What would you do for future trips?
- Would you waste time creating a better water purification system?
- Could someone build a business around a new water purification system? Would you?
- What data would you use and what are the bases for your choices?

A "process template" was designed to give them a means to gather and organize information. The four phases to their process were as follows: 1. define the market by doing market research, competitive benchmarking, and ethnography of the customer; 2. generate ideas for a viable product by brainstorming and reviewing existing solutions; 3. choose the best option by taking into account market research, available resources and a company's mission; and 4. make a case for your selection by presenting it to the group.

The agenda was as follows:

Day 1

Time	Activity/Content
10:00 am 60 min	Introduce Seminar • Discuss objectives and expectations • Video on Silicon Valley • Discussion of video o What type of culture needs to exist between a university and the marketplace? o If you have an idea, who will fund it? o How can students make valuable connections?
11:00 30 min	Who is Here • Participant Introductions o Why are you here? o In five years, describe your dream job.
11:30 30 min	Pre-assessment • Assess prior knowledge • Discuss why this content is relevant
12:00 60 min	Lunch (delivered)
1:00 90 min	Content Overview • Business overview and model • Engineering design process
2:30 15 min	Present Synopsis of Product Development Case • "SweetWater" and the guiding questions
2:45 45 min	Discuss Team Activity • What is the market for this product? • Break into small groups of 3
3:30 15 min	Feedback on Today's Activities

DAY 2

Time	Activity/Content
10:00 am 45 min	Video on Revenge of the Nerds • Discussion on
10:45 30 min	Product Idea Overview
11:15 30 min	Team Work • Conduct market research
11:45 75 min	Lunch (Double Dave's Pizza)
1:00 90 min	Crash Course in Effective Group Collaborations • Improvisational exercise • Business process • Marketing your product
2:30 30 min	Team Work • Work continues in your small group • Feedback on today's activities

Day 3

Time	Activity/Content
10:00 am 60 min	Video • Discussion of
11:00 am	Team Work • Prepare presentation
12:00 60 min	Lunch (delivered) • Guest lecturer – engineering professor who is creating a start-up
1:00 30 min	Continue Team Work • Finalize presentations
2:30 30 min	Presentations (10 minutes each) • Collectively as group we'll decide which option to go with • Who agrees/disagrees with your perspective?
3:00 30 min	Discussion and Decision Making • Which product would you choose and why?
3:30 30 min	Presentation of the Actual Sweetwater Case • Case conclusion presented
3:45 15 min	Feedback on Today's Activities

The collection of ongoing feedback from the student participants was integral to the evaluation of this short course. We solicited their comments and reactions to the agenda and activities, and the results are described in the next section.

Pilot Results
On the first day of the short course, students indicated their reasons for attending the course. There are three major reasons that the students give for attending the course. These are: a desire to start their own business, a desire to gain general knowledge about business issues, and a desire to gain specific knowledge for a special introductory section of the capstone design course which will couple engineering teams with MBA students. The responses showed that 25% of the students are interested in starting their own businesses, 58% were seeking general business exposure, and 17% wanted to get a jump start for the capstone design project. One student commented that she was in the course because she "didn't want to work in a cubicle."

On the first day, a brief presentation was made about the design process using Quality Function Deployment (QFD), and function matrix formalism used in design. The students were primarily mechanical engineers (67%), with representation from electrical engineering (25%), and chemical engineering (8%). The mechanical engineering students were well grounded in the formalism of design as taught from the QFD approach, and interestingly, the electrical engineers who had never seen design discussed in this way were quite interested in learning more about the approach.

Several of the students indicated that they learned quite a bit about the roles of various parts of any given business through the review that we conducted. Uniformly, the students enjoyed the 30+ minute video about Silicon Valley (Silicon Valley: A 100 Year Renaissance). Following the video, we discussed the necessary ingredients to spark an entrepreneurial cultural shift at UT. The students were prompted to look at grass roots mechanisms to facilitate cultural changes within the University.

The major value added to the students on day two appears to be related to the group and team dynamics. The student comments show that there are many aspects of group work that they had never been formally exposed to, and they seemed positive about having received the brief exposure to it in the short course.

The exit survey showed that the only major problem with the course was a somewhat disorganized coursepak. Articles were taken from various sources. There was no table of contents, and the articles were not sequentially numbered. Apart from this, the reviews were quite positive. A major value added on the third day was the appearance of a mechanical engineering professor who is on leave with a funded start-up discussing how he took his technology from an idea to a business. Of the activities shown in the course agenda on the previous page, the students unanimously responded that all components should be kept.

We were quite surprised by the overwhelmingly positive reception to the first roll-out of this course. In hindsight, given that this was a self-selecting group, it is not that surprising. What this shows is that there is some fraction of the engineering student body that has a real interest and hunger in learning more about business issues related to engineering. Subsequent offerings of this course will continue to focus on the needs of this target audience.

Resource Development

In addition to traditional, printed educational resources and the use of PowerPoint presentations, the Faculty Innovation Center is developing interactive, multimedia modules that give students the freedom to explore business concepts in a novel, self-paced environment. With the proliferation of the Web and its use in education, we felt that students would want to have access to materials in an on-demand manner. Electronic resources can be used in actual classroom instruction and are also available to students as they deem appropriate, either as students or when they enter the workforce.

One of the primary goals of the short course is to identify and describe the function and properties of agents in a business process. The various units of a company work together as an integrated whole and engineering is a vital part. Using a flowchart style graphic, the students are given a bird's eye view of the various flows (i.e., product, data, and cash) within a typical company. The schematic below shows an entire data flow within a typical company. To increase the level of granularity, the student can click on the shaded region for a detailed look at data flow within financial units.
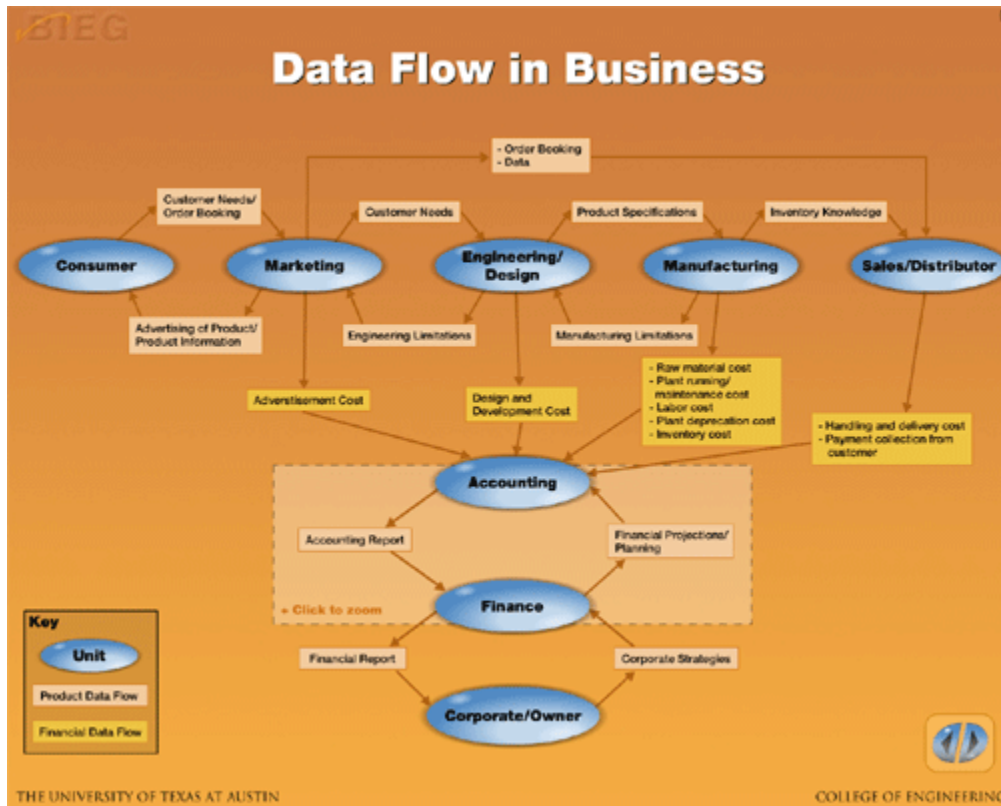
While this graphic is packed with information, it is a purely theoretical device, *describing* how things work instead of *showing* the internal and external interrelationships upon which business is built.

So, to address this issue, a series of interactive modules are being built. Each module relates the experience of a fictional character corresponding to a unit within the business model. The characters interact with one another during the cycles of product development, marketing, finance, and management, imbuing each of the theoretical business model units with a humanized exemplar. This approach adds a narrative element to the learning process, turning the business model into an interactive "story" with multiple perspectives. In non-linear fashion, students can choose which perspective(s) they wish to focus on, all the while piecing together for themselves the complex personal relationships that drive business.

For example, the character that represents the marketing cycle, Mary, interacts with nearly every business unit during her experience, including Derrick the Design Engineer, who meets regularly with Mary to discuss market needs, feedback from focus groups on prototypes, and analysis of sales figures to determine which features future iterations of products should incorporate.

Mary the Marketer hard at work

A screenshot of Carl the Customer's experience module

Each module is built around a common template. Using the simple navigational convention of forward and back buttons, students can progress through the characters' experiences at their own pace. The text to the right of the image area details each particular point in a character's experience. It might, for instance, explain that Carl the Customer has just watched a TV commercial Mary the Marketer created to promote her company's new product. Business concepts regarding marketing, advertising, and the importance of sales figures might also be reiterated in this text area. The flowchart in the lower half of the screen grows in complexity as the student clicks through the module, progressively revealing all the units within the business model with which the character interacts. The entire interface can be thought of as a "behind the scenes" look at the various cycles that propel business in its operations.

Eventually, animation will be incorporated into the modules, bringing the characters to life and strengthening the narrative aspect of the learning experience. Plans to incorporate audio read back of the content are also underway.

Summary

Engineering students are schooled in theory, design and analysis, but seldom are they asked, "How do you know if you have a good idea? And if you do have a good idea, what do you need to know to make that idea viable in the marketplace?"

Our experience in this short course is that there are students who have sufficiently strong interest in business topics are willing to sacrifice their time to learn more and improve themselves for a

non-credit course. To address the needs of these students, we found that case-based teaching where the students experience the cases provides an interesting mechanism for unfolding a business story. Each team of students designs a product and then writes a slightly different business justification tale. The actual business case for that product and entrepreneurs in the same scenario is detailed after they have scripted and pitched their story. Allowing them to first suggest their solution is a good way to decipher their initial understandings and then build upon those with the case solution.

We also found that through discussions, the students gained an intuitive model for the roles and tasks of business units. This new understanding allowed them to gain a perspective on how engineers function within product businesses. Even though all of the students were engineers, we found that the mechanical engineers had a much stronger design background and that a primer on design is necessary for the other engineering disciplines.

We learned that a multidisciplinary team of instructors was required to provide the balance and context required to cover the various topic areas with appropriate levels of assessment and evaluation. Future offerings are under development. We are working with a student leadership group to refine the curriculum and to possibly offer this workshop as a one credit course.

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