Industry Case Studies at Texas A&M University

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Abstract

In the Dwight Look College of Engineering at Texas A&M University, the college and industry have partnered to present classroom case studies, model the engineering profession, support curricular efforts, and offer student workshops. Many faculty members bring industry into the classroom in senior or capstone design classes, but ***NOT*** in meaningful ways at the freshman level. An important difference in the TAMU partnership with industry is that efforts are focussed on first-year students. Both partners are working to prepare the very best engineers possible, and there is a growing group of industry teams who come to campus several times each semester to offer different services for different levels of students. This paper will concentrate on the case studies that industry partners prepare and present.

Case studies are an effort to demonstrate "real world" engineering to currently enrolled engineering students. Companies usually send a team of 2-8 engineers who spend their day with students in an engineering course, typically a first semester, freshman engineering course. This team typically presents a 15-20 minute overview of a problem encountered in their company or industry. Students break into assigned teams, generate possible solutions to the problem, and then student teams present their solutions to the class. In the discussion that follows, the industry team presents the solution selected at their company and reviews the major contributing factors to the decision. In addition, the students are able to enter into a question and answer period with engineers from industry about their work environment, greatest challenges, rewards, etc. Companies that have presented case studies include Accenture, Applied Materials, Compaq Computer, Exxon Mobil, FMC, Lockheed-Martin, Motorola, Texaco, and TXU. As an example of the scope of the project eight companies presented case studies to almost 2,000 students during the 1999-2000 school year. The paper will describe the process for organizing case studies, examples of actual case studies, benefits for the students, benefits for the companies, and obstacles that are being overcome.

Why did this get started?

Most students enter with little or no understanding of the opportunities that are opened by completing a B.S. in engineering. In particular, most students have at most a vague idea of the practice of engineering. With little knowledge about what engineers do or how an undergraduate engineering degree could assist their realization of career and/or lifelong goals, students form their impressions of careers after graduating with an engineering degree based on their experiences in lower division courses in science, engineering and mathematics as well as conversations with other students and faculty. In general, experiences in these courses discourage students. Based on the work by Seymour and Hewitt[1], lack of/loss of interest in science, engineering and mathematics is principal concern mentioned most often as a factor that encourages some engineering students to change their major to something different from engineering. It is also one of the concerns mentioned most often by students that elect to stay in engineering[1]. Therefore, the Dwight Look College of Engineering (COE) at Texas A&M University has been exploring ways in which lower division courses could increase the motivation of students without sacrificing academic rigor necessary for success in upper division courses and after graduation.

Several strategies have been developed to help students develop a better understanding for the practice of engineering and the breadth of issues that must be considered in actual engineering problems. One strategy is to offer application problems: problems that require students to apply concepts of science, engineering and/or mathematics that are currently under study to a problem that has real-world elements. This strategy was used frequently in the calculus reform efforts.[2] Another strategy is to develop one or more case studies of actual engineering problems, particularly problems that students are likely to recognize or identify with.[3,4] Although both strategies have helped students develop a firmer grasp of the practice of engineering, neither provides students with opportunities to personally engage practicing engineers. In addition, from the perspective of the college and their connections with employers, neither strategy builds closer relationships between the college of engineering and the companies that employ their graduates. Therefore, the college elected to explore possible additional strategies.

How Did This Get Started?

In the spring of 1998, Associate Dean of Graduate and Undergraduate Programs, Dr. Karan Watson, met with the COE External Advisory Council to discuss changes in the first and second year classroom. At that time she talked about principles behind the learning communities that were being created, changes in classroom pedagogy, and integration of science, math, and engineering. As the COE defined learning communities, they included students, faculty, and industry. She told the Council that the College needed help bringing industry into the first year classroom in meaningful ways. The College believed industry interaction could increase the commitment of first year students to study engineering, and therefore, retention of the best students. She asked for their help. There was a short discussion of possible ways industry could help and most of the members of the Council were ready to invest the time and people resources needed. The group agreed on a meeting in the summer of 1998 with industry representatives, faculty, and administrators from the College.

In June 1998, representatives from nine companies, ten first-year faculty, and three college administrators gathered. We met for six hours in a one-day face-to-face meeting on the Texas A&M campus. All the industry representatives were from Texas-based companies. The

Associate Dean presented the same information she had at the College External Advisory Council. We then asked the question of the entire group, industry and faculty, "How could industry be involved in the classroom in the first year engineering course (ENGR111)?" The brainstorming session produced the following ideas:

- Adoption of a team (of 4 students)
- Adoption of an entire cluster (of 96 students)
- Industry teams would visit their team/cluster 3-6 times a semester
- Industry would develop team projects for a 3-4 week duration based on "real world" problems and the student's skill level
- Industry would help in the introduction and evaluation of projects
- Industry would serve as e-mail consultants to team/clusters
- Deliver course lectures on subjects such as ethics, design process, documentation, teaming, and/or communications
- Host cluster for a field trip to industry
- Develop a case study to be presented by engineers in the classroom
- Send new hires back to the classroom to discuss perceptions and realizations of the workplace
- Send an experienced engineering to talk to the class about their projects
- Conduct industry training like teaming, conflict management, communications, etc.
- Industry do mock interviews, resume writing, dinner with discussion

Once different ideas had been generated, the faculty and college administrators met and decided upon several criteria that could be used to prioritize the ideas based upon the needs of the students, learning objectives of the courses, and constraints imposed by learning environment. The following criteria were generated for the interface between industry and students:

- It should happen at least once each semester;
- It should be in the classroom;
- It should address teaming as a major concept;
- It should emphasize basic sciences and show relevance of physics, mathematics, etc.;
- It should be delivered by a team of industry engineers instead of a single engineer;
- It should provide an opportunity for students to interact with a diverse set of engineers; and
- It should provide a glimpse of what engineers really do.

During discussions several significant questions that would need to be addressed in the development of the industry-student interface:

- How much mathematics, science, and problem solving skills do first year students have to be able to solve "real world" problems?
- Would an industry intervention be worth the time given from actual course material and would the intervention add value to the course and students? Answers to this question are provided in the section entitled "How is it working?"
- Could industry with the current consolidations and cut backs, afford to send a team of 4 to 8 engineers and could they afford the time to develop the case studies and/or projects?

- How could the college and industry maintain the interface over time?
- Would this involvement be worth the time spent for: industry, students, faculty, and college administrators?

Answers to the first question would be hammered out during interaction between College staff and faculty and industry representatives. Industry representatives were interested in how much students knew in order to prepare the case studies. College faculty and staff would provide answers based on their knowledge of student backgrounds and the course materials. Answers to the remaining questions are addressed in the sections entitled “How is it maintained?" and “How is it working?"

After much discussion, a two-hour case study delivered by industry teams in the regularly scheduled class time was selected as the first interface to try for fall 1998. There were 14 sections of ENGR111 with 96 students each and 2 honors sections of ENGR111 with 52 students that hosted industry teams for case studies. The case studies took the entire 1 hour and 50 minute class period. Industry teams were made up of 2 to 8 engineers. The companies were very cognizant of sending diverse teams that represented both sexes, many races, and multiple disciplines.

What happens?

Case studies are an effort to demonstrate "real world" engineering to currently enrolled engineering students. Companies usually send a team of engineers that range from 2 to 8 members. A background reading packet [and homework] for the students often precedes visits. The industry team typically presents a 15-20 minute overview of a problem encountered in their company or industry. Students then break into assigned teams, generate possible solutions to the problem, and then present their team solutions to the class. The engineering team then leads a discussion that reveals the actual solution and reviews the major contributing factors.

To help readers better understand the nature of the case studies and what students might take away from a case study, several example case studies are described below.

Company: Applied Materials, Inc.
Case Study Title: Semiconductor Process Equipment Cathode Base Field Failures
Description: This case study will introduce the student to issues associated with engineering design, quality assurance, manufacturing, cast, non-conforming material, and supply chain management. These aspects of business will be explored by addressing product failures in multiple geographical locations including customer facilities in Asia, thus requiring the student to also address the various intricacies of communicating across cultures.

Company: Exxon Chemical Company
Case Study Title: Critical Care - A Case Study in Problem Solving and Team Work
Description: This case study takes place at the Exxon Mobil Baytown Polypropylene Plant, a world-class production facility. A young engineer, 2 years out of Texas A&M, is faced with a major problem of odor in the polypropylene product. This young engineer must move quickly

assembling an effective and highly skilled technical team to solve this problem as ExxonMobil's number one customer is experiencing problems with their product.

Company: Lockheed-Martin Tactical Aircraft Systems

Case Study Title: F-16 Common Missile Warning System

Description: The engineers at Lockheed Martin Tactical Aircraft Systems are constantly working to expand the operational capabilities of the F-16 Fighting Falcon. Past improvements have included electronic countermeasures, infrared detection devices, and environmental control systems that serve to enhance the safety and reduce the vulnerability of the aircraft. The case study will give the students an opportunity to determine the optimum number of sensors and their placement on the F-16 Fighting Falcon to effectively detect missile threats in the operational sphere of the aircraft.

Company: Texaco E&P, Inc.

Case Study Title: Getting Natural Gas to Market

Description: Industry representatives from Texaco will present an engineering problem related to the delivery of a volume of gas from a well location to a point where the gas may be sold. The students will see a typical approach to engineering problem solving and decision making. At the end of the class the students will understand that there is more to an engineering problem than putting numbers into the correct equations.

Company: TXU Electric Services

Case Study Title: Install COHPAC at Big Brown Steam Electric Station

Description: TXU Electric's Big Brown Stream Electric Station's two 575 MW, lignite fueled units are located in Freestone County, Texas near the town of Fairfield. The units were first commissioned in 1971 and 1972. Although the units complied with state regulatory requirements for mass emissions, they could not consistently meet the opacity limit when operating at full load. In 1990, the State announced even more stringent requirements for opacity that prompted TXU Electric to explore alternatives to modify the units in order to meet the new opacity limit.

Company: TXU Electric

Case Study Title: Commanche Peak Steam Electric Station - Nuclear Power Generation Facility Industry Notification Analysis

Description: The Commanche Peak Steam Electric Station (CPSES) has been notified by the Nuclear Network that the potential exists to overspeed auxiliary feedwater pump steam turbines. An overspeed condition could result from either: too much water entrainment in the incoming steam to the turbine; or the governor valve stem may not move freely to properly control and steam flow to the turbine. Students will determine if CPSES is susceptible to the problem, and if so, what immediate and actions should TXU Electric consider to address the potential problem at CPSES.

Companies have not received legal clearance to publish the case studies, so the COE can share them with the engineering education community.

How is it maintained?

There is an administrative staff person who spends approximately 25 percent of her time working with the Learning Communities. The College covers her salary. She is responsible for maintaining industry interfaces, soliciting new industries, raising funds to support interfaces, planning evaluations on industry interfaces, and supervising a half time graduate student. The graduate student is paid from funding raised through agency grants. She is responsible for coordinating industry visits, arranging calendars, evaluating each case study, distributing case studies to faculty, and corresponding with industry and faculty. Other incidentals incurred by industry visits to the College like lunch, thank you gifts, snacks, etc. are provided by private support to the Learning Communities.

It has been much more challenging to establish an on-going industry-academia interface for the sophomore courses. The technical content of these courses is at a significantly deeper level than the first-year courses. Also, the content of the sophomore courses varies considerably from course to course. With five courses at the sophomore level for engineering sciences, it has not been possible to build a single interface through which industry can generate case studies to fit all five courses. Therefore, to help industry representatives create case studies that will be helpful to students, faculty involvement in ongoing conversations is much more necessary than in the first year courses. Helping faculty set aside the necessary time to work with industry to construct the case studies for the sophomore courses has not been accomplished in general. A small number of case studies have been generated, but case studies are not consistently used in the sophomore courses.

How is it working?

The 2000-01 academic year was the third year in which employers have presented case students to over 1600 first-year students. Students, faculty and practicing engineers seem energized by the case study presentations. All three parties derive mutual benefit from the partnership. Initially offered only to students in ENGR 111 [the first semester first-year engineering course], case studies have been expanded to include ENGR 112 [the second semester first-year engineering course], starting with a pilot in the spring of 2000 and growing to ***all*** classes in 2000-2001. When asked to help recruit more companies to support this doubling of the case studies (one in ENGR 111 and one in ENGR 112), all companies opted to increase their efforts rather than *share the wealth*. Other evidence of the success of case studies include their use at other universities by the industry partners who prepared them and the comments received in post-study evaluations.

At the end of the case study presentations, survey forms are distributed to students, industry teams and faculty members. All participants provide comments that are used to improve the presentations in the next iteration. A graduate student compiles the comments and generates summaries. The following paragraphs include summaries of the comments from students, industry and faculty for Fall Semester, 1999-2000 academic year as well as more detailed information.

Students - From the students' perspective, engineering takes on a whole new meaning when they are able to make the connection between the classroom and the real world. Industry practitioners help in this bridging process by using actual day-to-day engineering problems to demonstrate the practical applications of engineering principles through case study presentations. From a survey of first-year students, we find that a good proportion have been able to reinforce their career choices after interactions with industry practitioners. There is indication of improved problem solving skills, increased awareness about teamwork and the engineering profession as a whole. The majority of the students surveyed feel like this type of cooperation between industry and academia should continue.

Figures 1-4 summarize student responses to a case study offered by Texaco. Similar summaries are generated for each case study. In addition, 40-50% of the students responding to another question on the survey did NOT have a least favorite part of the case study.

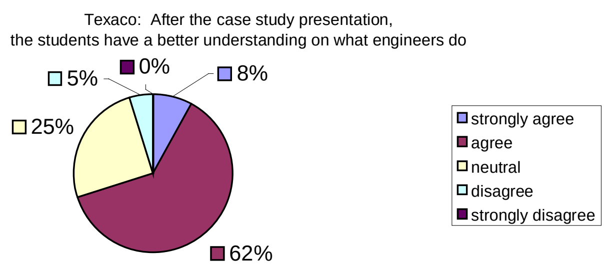

Figure 1. Do you have a better understanding of what engineers do?

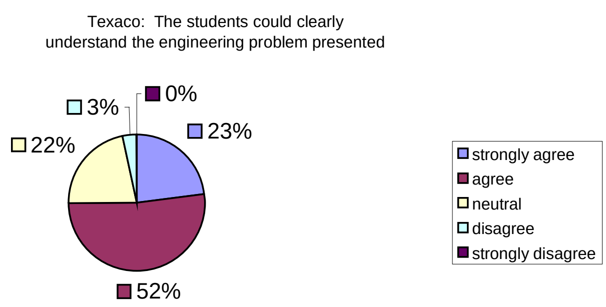

Figure 2. Do students understand the case study as presented?

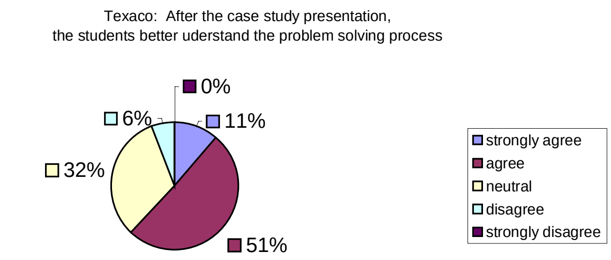

Figure 3. Do students understand the problem-solving process?

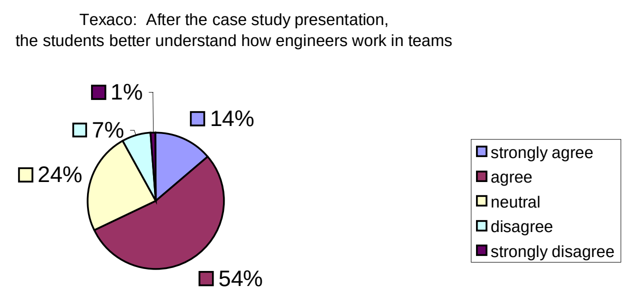

Figure 4. Do students understand how engineers work in teams?

Faculty - At first faculty members who taught the first-year engineering courses were concerned about introducing case studies. First, they were reluctant to allocate valuable class time to the case study because they felt that they could barely cover the existing material. Second, they were concerned that the technical level of the industry presentation would be too low for the first-year engineering students and would fail to help them understand why knowledge of mathematics and science are essential for practicing engineers. Third, they were concerned that the technical level of the industry presentation would overwhelm the first-year students. Administrative encouragement helped convince faculty members to try using case studies. Now, faculty members involved with the first year engineering curricula agree that industry involvement in the classroom helped reinforce their teaching. In particular, the industry case

Table 1. Faculty Comments on Industry Case Studies

"The students were able to develop reasonable solutions using their abilities to read drawings and geometric relationships. They could also extend beyond these simple tasks . . ."

"{They} reinforced many {course} objectives; too numerous to list."

"The students seemed to enjoy it and were quite responsive"

"Excellent job! The level of presentation was very good (on target). A team of 7 engineers in a class of 50 students worked very well for personal interaction & milling around the room addressing questions"

“A good job. They asked for responses and got some back. Then they hung around and talked after class. This is really what the interested students liked most . . ."

"The point is that some real live engineers were nice enough to take some time 'off the clock' to show our students what they did for a living besides grinding out math, physics, and chemistry problems"

study presentations gave practical demonstrations of the engineering principles as well as bringing into focus the social and economic issues that impact engineering in the real world. Such demonstrations of the relationship between practicing engineers and others involved in decision-making help to give a different meaning to engineering for the students. Industry practitioners have provided props and demos, helped develop web sites and supplied engineering tools that have been found useful in enhancing the classroom experience for students. Being able to feel, touch or experience the actual products of engineers' efforts provides a necessary bridge between theory and practice. There have been indications that this helps students through the first year of the engineering training and even beyond. Table 1 contains some specific comments from first-year engineering faculty members.

Industry - Some of the benefits identified by industry participants include professional development of the industry personnel; increased visibility and awareness of their industry; efforts to improve retention of women, underrepresented minorities, and honors students; opportunities to serve as role models for students, and early identification of students for hiring programs. Professional development of individual engineers, one of the requirements of the professional body of engineers can be fulfilled on this level. Engineers helping engineers at a very early stage of their careers has been a rewarding experience for industry practitioners. By interfacing with faculty members, cooperative efforts are more easily developed on projects at both academic and industry levels. Recently, industry practitioners have indicated their interest in having faculty members make site visits to better foster these relationships. As industry partners have returned they have adjusted their presentations to make them even more interactive. Most of the teams have become very adept at engaging the students and having fun.

Table 2 contains some specific comments from first-year engineering faculty members.

Table 2. Industry Comments on Industry Case Studies

"In my mind, most students don't have a clear idea of what engineering really is on a day-to-day basis. I know I didn't while I was in school and I think the opportunity to hear "How much calculus do we use?" and "How many problems do you solve?" type questions is really valuable. Somebody needs to tell them that they can't be in the club without calculus." Karen Mappin, Motorola

"The students came up with an actual fix in one group. A lot of the ideas they [students] had were the same or similar to the ideas we considered." TXU Electric CPSES

"It takes several steps like these, but I believe the nature of our problem: students working a real, multi-disciplinary engineering problem will at least give them a preliminary sense of whether or not they're interested in the engineering industry. Maybe they like it, or maybe they see they'd be happier somewhere else. In my case, engineering school was very theoretical. If I had a class like this I would have seen that the challenges of industry were enough to keep me interested.” Jamie Fougerousse, Lockheed Martin Tactical Aircraft Systems

Conclusions

Continued industry support allows Texas A&M to continue offering, and even expanding, case studies in first-year engineering courses. The following points summarize the benefits to all the partners involved.

- Companies value the opportunity to get their names in front of first-year students. Practicing engineers enjoy the opportunity to give back to their profession, treat the experience as professional development, and have fun doing it.
- Students are able to reinforce career choices, to make the connection between the classroom and the real world, and to improve awareness of the need for teamwork and problem solving skills.
- Faculty found that case studies reinforced the objectives of the course, in particular a practical demonstration of the need for engineering fundamentals.

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