

2007: THE MOVE TO INDUSTRY SPONSORED CAPSTONE DESIGN PROJECTS – WHY AND HOW

Jack Zable, University of Colorado – Boulder

Dr Zable was recently named The Industry Professor of Mechanical Engineering Design, a new chaired professorship position. He created and has directed the new capstone design program in the mechanical engineering department for the past seven years. Prior to joining the mechanical engineering faculty, he held various management and high level technical positions at IBM. He was a member of IBM's prestigious Academy of Technology. He is an ASME Fellow.

The Move to Industry Sponsored Capstone Design Projects – Why and How

Jack Zable

Introduction:

The Mechanical Engineering Department at the University of Colorado at Boulder (CU) decided to change its two course capstone design sequence in such a manner that the design projects were almost entirely comprised of industry sponsored projects. This was initiated after the completion of a small study comparing three projects from industry with three student selected projects. Some of the results of these comparisons are given in this paper. The implementation of a new industry sponsored capstone design program is also highlighted, along with the myriad of barriers that had to be overcome. At the time of the comparison, 1999, student teams in the capstone or senior design course were formed, more or less, on a friendship basis, with each team working on a project of their choice. Many of the projects selected by the student teams dealt with sports equipment, and other devices with which the students had some familiarity and interest. It was felt that these projects had limited value with respect to what students might ultimately undertake in most industry environments. One goal for a capstone design course is to better prepare students to enable them to succeed in their future careers. Thus, an industry based experience seemed to be more appropriate. Additionally, the primary driver for the student teams to excel in a self-selected projects environment was their grade for the course. For the most part, there was no receiver for their completed design and hardware, and as such the results of their efforts were eventually discarded. Coincidentally, at this point in time ABET requirements were being modified to put a much greater emphasis on the educational role of the capstone design course sequence.

Comparison of Projects:

With this as a background, in the fall of 1999, three capstone design projects were obtained from three companies in the Boulder, Colorado area, on a no fee basis, for each of three student teams. The first of these projects required the student team to design and build equipment to measure the thickness of a beverage can to within ten millionths of an inch. The second project required the students to build a life testing device for gears that operate in a vacuum-type of environment. The last project involved the design and development of all of the manufacturing fixtures required to automatically assemble a tape drive subsystem. The educational experiences of the teams working on these projects were ultimately compared to those of the teams working on self selected projects. The student selected projects were; the design and development of an adult pogo stick, the design and development of an automated height adjustment mechanism for a bicycle seat, and the design and development of a quick adjust snowboard binding. The same instructor was the faculty advisor for all of these six teams. At the end of the academic year, comparisons were made between the industry projects and the self selected projects relative to their educational value to the students. Other factors were also considered such as employment potential.

Results of the Comparison:

The industry projects were superior to the self selected projects for several important reasons. Some of these are listed below:

- a) For the industry projects, all design reviews were conducted by a team of experienced engineers. The reviews conducted by experienced engineers were an excellent learning

experience for the students, and one that they would, in all likelihood, encounter later in their professional careers. Many practical aspects of design were discussed at these reviews.

- b) The students were guided by industry experts, industry mentors, as well as by their faculty advisor. In many instances the industry mentors introduced and taught the students to use new tools that were pervasive in their specific industry. The use of other important tools, such as GD&T, FEA, etc., that the students had already learned in school, were reinforced in the strongest way.
- c) Additional company resources in the form of state of the art equipment, materials, and help from experienced technicians were made available to the students involved with these industry projects. These projects were all performed with companies that were within 10 miles of the CU campus. At the time that this comparison was made, the equipment available to these students within the mechanical engineering department was less than wonderful. This last issue has since changed dramatically.
- d) The industry projects were quite meaningful because their successes were important to the sponsoring company. Additionally, these projects were quite valuable to the students because they closely resembled projects, both in content and operation, that the students might see once they started their careers.
- e) The external pressure on the student teams to finish the project in a timely and professional manner was apparent.
- f) The overall quality of the completed industry projects was better than that of the completed self selected projects. At the end of the capstone design course sequence, two of the industry projects completely met specifications, compared to none for the self selected projects.
- g) A permanent or intern employment opportunity was given to one student on each team.

One positive aspect for the self selecting projects was that the students were working on a project that was important to them.

This comparison led to the conclusion that the department needed to move in a direction where the great majority of the capstone design projects were industry sponsored. Additionally, it was expected that the department would be able to obtain much needed resources from the industry sponsors in the form of equipment and/or project fees. The goal was clear, however, the \$64 (key) question was the path to take to accomplish this goal. In other words what were the significant barriers that would prevent the establishment of an industry sponsored program, and how could they be overcome.

Industry Sponsored Program Barriers:

The most obvious barriers for having a successful industry sponsored capstone design projects program were believed to be;

- a) Obtaining a suitable number of meaningful industry sponsored projects.
- b) Getting the design faculty of the mechanical engineering department to agree to teach in a program where the capstone projects were predominantly industry sponsored. It was expected that there would now be pressure put on the capstone design faculty as well as the senior students involved in the program to succeed. This was expected to result from the expectations of the industry sponsors, as a result of the sponsorship fees paid.

- c) Gaining the support of the rest of the mechanical engineering department and, in fact, the engineering school to establish this program. This was to be a relatively new program for any of the engineering departments at CU.
- d) Resolving many legal issues such as liability, intellectual property rights, contractual issues and the like. Working with attorneys whose interests might not be aligned with yours might be considered a challenge.
- e) Convincing the students that this program would be of great benefit to them, even though it meant that the students would not work on self selected projects.
- f) Having projects that were to ultimately be interdisciplinary in nature. There had to be buy in from sister departments within the engineering school.

Gathering Data to Help Overcome Some of the Barriers:

The first step taken was to obtain data from other departments/schools that already had established industry sponsored capstone design programs. A mini-survey of fourteen departments/universities was conducted. The key pieces of survey data collected at the time, in the year 2000, were:

- a) In 10 of the 14 programs, the sponsoring company was allowed to have exclusive ownership of the intellectual property developed during the project.
- b) The average sponsorship fee was \$15,000.
- c) Twelve of the departments had a two course capstone design sequence.
- d) On the average, advising three to four teams per semester was equivalent to teaching one course.
- e) Most of the schools did not have multi-disciplined teams.
- f) The size of the student teams typically ranged from 4-6 students.
- g) Sample contracts were obtained from a few of these schools.

Overcoming the Barriers:

Buy In From Design Faculty: This was relatively easy since some of the design faculty in the department had already worked in industry, some were very interested in establishing stronger contacts with industry, and almost all were intrigued by the potential challenges of this new program. All were convinced that this type of program would be of greater educational value to the students.

Buy In from the Department and College: The department was shown the project comparisons mentioned above. The educational value was quite apparent. They were also told that based upon the mini survey conducted, we should be able to obtain a fair amount of income from the sponsored projects. This income would then primarily be used to; obtain state of the art equipment for our students to use, upgrade our student laboratory space, and upgrade the general facilities of the department that were used by our students. Finally, it was originally believed that this new program would only modestly tax the teaching load of the department. At that time, both the dean of engineering and the associate dean of engineering (education) were extremely supportive of this new program.

Intellectual Property and Other Legal Issues: Many companies, when queried about sponsoring a capstone design project, strongly suggested that the intellectual property developed during such a design project should belong to the sponsoring company. Alternatively, legal and technology

transfer personnel within the university wanted to own these intellectual property rights, and then license them exclusively to the sponsoring company. The latter, in fact, was the agreement used during the first year of the industry sponsored projects program. However, the sponsors, and in particular their attorneys, were unhappy with this agreement. An improvement to this initial agreement was needed. After many meetings with legal, technology transfer and contracts personnel from the university, a compromise agreement was established. In this agreement a dual fee structure was established for sponsoring projects, with a significantly higher fee charged to companies desiring total ownership of the intellectual property developed during the sponsored project. Additionally, agreements were established for the students and faculty to respect the confidentiality of such information presented to them by the sponsoring companies. Publication agreements were also established that would adequately protect sponsoring companies, and yet give students and faculty the option to publish. Liability issues covering students working on the site of a sponsoring company were also dealt with.

Obtaining Industry Sponsored Projects: There were a few factors that existed at the time that were helpful in convincing companies and government laboratories to sponsor projects. At the time the economy was quite robust, the Boulder region contained a fair number of companies and government labs, and the department had an existing but small industry advisory council. This industry advisory council was subsequently doubled in size in a relatively short period of time, with the stipulation that companies joining the council would do their best to sponsor capstone design projects. This is significant since the great majority of the project sponsorships came from council member companies and labs. The criteria established for determining the companies to invite to be members of the department's industry advisory council were:

- a) They had to have a significant presence in Colorado, or
- b) They hired a fair number of the department's students, or
- c) They were involved in technology areas that coincided to the strategic research directions of the department.

Additionally, we asked interested companies if they could provide a representative to the council that would come close to meeting the following criteria:

- a) Graduated with a mechanical engineering degree, and/or
- b) Graduated from CU, and
- c) Held the equivalent to a second level management position or above.

A base fee of only \$10,000 per project was charged, at that time, as an added inducement to sponsors. The companies were ultimately satisfied with the intellectual property agreements established. Multiple visits and/or calls were made to companies who were members of the industry advisory council, as well as other 'non-affiliated' companies.

As a result of this effort 18 industry sponsored projects were obtained. Additionally, the department elected to continue two SAE projects. At the time there were approximately 90 students in the capstone design class, and the number of projects obtained was deemed to be reasonable. A formal project center was then established called the Industry/University Cooperative Projects Center (I/UCPC). It was modeled after the NSF Industry/University Cooperative Research Centers.

Student Buy In: During the semester prior to the start of this new industry sponsored projects program, all of the students who were to be enrolled in the capstone design course were contacted. The new program was explained to them as well as the advantages the program offered to them. This included enhanced employment opportunities. Then at the very start of the capstone design course, this was reinforced. Additionally, a few students who had taken the capstone design class the previous year, and who had worked on one of the three industry projects, talked to the class about their experiences.

In order to facilitate students to work on those industry projects that most interested them, a unique team selection process and a unique project to team matching process were implemented. At the very start of the first semester the projects and the companies sponsoring them were described to all of the students. The students then filled out a team selection form listing; their five top project preferences, their GPA, their engineering type work experiences, their team mate preferences, and the names of those students that they did not want as team mates. Teams were then assembled based upon these criteria. The average GPA of each team was more or less the same, and each team was comprised of students who were neutral or wanted to work with each other. There was also a common thread of a project preference for each team. This process was completed at the end of the first week of class. The teams then had to write one page proposals to bid for the projects that interested them. It was suggested that teams submit proposals for approximately five different projects. The project proposals were immediately sent to each of industry mentors associated with the project related to the proposal. Each industry mentor rated the proposals of their respective project, and based upon these ratings, teams were matched to projects. This was completed during week three of the semester. Almost all of the teams were quite happy, at least initially, with the project that they received as a result of this matching process.

As an additional step to obtain student buy in, a limited number of juniors were allowed to join the capstone design team of their choice for the second semester of this program. It was felt that this step would also help future capstone design students transition into the program in the following year.

Results from the First Year of this Program:

The first year's projects were fairly successful, with many of the goals for the program being achieved. About 20% of the students obtained employment as a direct result of their involvement with this program. Resources from the project sponsorships were leveraged and then used to purchase much needed state of the art equipment for the student labs. For the most part, the feedback from students was quite positive. Based upon a rating system completed by the industry sponsors, almost all of the sponsors were satisfied with the results obtained. More than half of the sponsors were very satisfied with the result, and a few were extremely satisfied. The design faculty thought that this new direction was far superior to the previous one taken by the department with respect to capstone design.

However, there were problem areas that needed to be resolved. They were; the intellectual property contract, having one faculty member advise too many teams, team sizes that were too small (4 members), and the very limited interdisciplinary nature of the teams. Additionally,

some students were not as enthusiastic about the program because the projects were not self-selected. These problems and others that have occurred over the past seven years that have been more or less resolved are described in an accompanying paper entitled, "Improving the Results of a Capstone Design Program– A Continuous Process".