Some Best Practices in Industry-Sponsored Capstone Design Projects

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This paper reports on development, implementation, and adoption of best practices in working with industrial partners and industry-sponsored capstone design projects in engineering programs in Rhode Island in partnership with regional industrial partners.

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Background

Since the adoption of a capstone design outcome by ABET, Inc. in 1996 under Engineering Criteria 2000 (EC 2000)[1,2] there have been significant changes to the curricula of engineering programs and in particular capstone design curricula in Rhode Island. Significant emphasis has been placed on industry-sponsored projects as an effective method of achieving open-ended, real world, multidisciplinary, and team-based design experiences for engineering students.[3-6]

Representing two of the three Rhode Island Universities offering ABET EAC accredited engineering programs, we have developed a holistic approach to industry-sponsored capstone projects.[7,8] This approach is based on the best practices found in the literature, survey of other engineering programs, and our own combined experience of more than forty years of teaching and research in the capstone design area. In this paper we report the best practices we have found to be useful in working specifically with industrial partners.

In the realm of capstone projects, the category of "industry-sponsored" presents some of the most challenging as well as rewarding experiences for students. However, with a well-defined funding model, consistent and mutually agreed upon expectations and deliverables, a mentor team from industry that is committed to the educational process and engineering faculty cognizant of the subtleties of a business environment, a rewarding industrial university partnership can be developed.[9-11]

Academic Views and Conditions for Industry-Sponsored Capstone Design Projects

Capstone design projects generally fall into one of several groups, service or non-profit, competition, government, federal/state research laboratory, University generated, entrepreneur/inventor sponsored and industry sponsored. In most cases institutions adopt their own customized version of the capstone design experience based on a number of factors. These factors might include course length (one or two semesters), multidisciplinary or single discipline, team taught or single professor, university line-item funded or externally funded projects, additional requirements of the class such as integrating design textbooks and course deliverables.[11]

Successfully implementing industry sponsored projects into capstone design classes without the proper foundation and mutually agreed upon outcomes can lead to failure. In developing industrial contacts that lead to industry-sponsored projects, we have found the following elements to be the most effective to sustaining the partnership:

- Two-semester, three-credit design sequence (one academic year starting in September and ending in May)
- Initial relationships for industry contacts facilitated by proximity of the industry served by the university, for us this region is Rhode Island, Connecticut, Massachusetts, and New Hampshire
- Contacts from industry generated by alumni and recruiting managers at the companies and supplemented with an outreach strategy that includes invitations to capstone design presentations and showcase events at the end of the academic year
- Mutually agreed upon common view of the project and results expectations among all parties (industry partners, professors, and students)
- Funding model meeting both University and company requirements
- Faculty teaching capstone design courses taking an active role with industry in all phases of the project definition, execution, reporting and post assessment
- Intellectual property issues addressed in advance of the project start with proper documentation and releases generated and signed by pertinent parties with the recognition that in most cases the universi-

ty will need to give up claims to intellectual property in order to work effectively with industry

In our experience, we have found that increasingly better results for the projects are achieved by the experience of working with the same company over several years. Furthermore, projects with individual "inventors" and very small companies (less than 10 people) typically exhibit more turbulence and uncertainty in project definition, start up, execution, and end results.

Industrial Views and Conditions for University Design Projects

The primary goal of any company is to become and then remain profitable. There are many motivations for why a company would want to support a capstone design project but in the end, most see working with universities as a means to help achieve their company objectives. In addition, most companies have a value system that embodies contributing back to the communities where they operate. Consequently, the best opportunities for universities in building relationships with industry partners exist locally since most companies have outreach programs to their regional universities. These connections are an effective way to establish relationships with companies providing the prerequisite to developing capstone design project connections. In some cases, the university may have a program that is internationally recognized and then the proximity location is not as important. For example, the International Engineering Program (IEP) at the University of Rhode Island is an internationally recognized program where engineering students double major in foreign languages (German, French, Spanish, and Chinese). At Roger Williams University, students have worked with company sponsors "remotely" using technology as the communication bridge. However in the end, the most successful projects in our experience are those that allow students to experience first-hand the sponsor's operations and periodically meet face to face with industry mentors.

Mapping Industry-Sponsored Design Projects to the Academic Calendar

The timetable of capstone design projects at universities is relatively fixed and very different than the timelines established in industry. Industry projects can generally start any time and end as appropriate. The academic calendar of universities determines the start and stop time for the projects in contrast to competition design projects for example, that are date specific. Therefore, it is very important to communicate these timelines with industrial partners and lay out the project plans in such a way that students can accomplish their goals and meet their deliverables within the constraints of the academic semester (or quarter) boundaries. We have established the following schedule for our projects that seems to work very well with the industry projects.

Fall semester

- Define the problem
- Develop design specifications
- Plan and manage the project
- Research possible solutions or supporting information
- Generate concepts (minimum of 3)
- Evaluate each concept using engineering tools/ analysis
- Evaluate the competition
- Design using engineering tools/analysis
- Develop proof of concept(s)
- Present/defend the design through critical design reviews (2 presentations per semester)
- Document all steps and preliminary design details in a comprehensive technical document

Spring semester

- Build/implement the final design
- Develop a test engineering plan and test the design
- Redesign or make improvements based on the test results; implement the improvements
- Test again, improving the test scope if appropriate
- Improve the design and implement the improvements
- Present/defend the design through design reviews (2 presentations per semester)
- Document all steps and final design details in a comprehensive technical document
- Present final design in a design showcase to industry representatives, faculty, fellow students, and the community at large

Funding

Funding is critical in industry-sponsored design projects as with all projects. For our requirements, all industry projects must require some type of prototype or proof of concept. Projects can have varying expenses depending on their complexity and details. We have adopted three main models for funding design projects:

1. Full industry sponsorship where the company agrees to cover all costs and expenses associated with the project. Most of the work will be performed at the laboratories or machine shop at the company location. Students will need to travel to the company location to manufacture and build their prototypes. Students submit all expenses to the company.

2. Joint company and university sponsorship where some of the work will be completed at the company and some of the work will be undertaken at the university. Industry will provide some funding to the university to cover the expenses and overhead at the university. Typically, faculty and staff time are not charged directly to the project. However, indirect expenses can be covered through overhead. If the university operates a cost center for some of the services (e.g., machine shop) then those cost could be directly charged.
3. Company provides funding to the university to cover all expenses associated with the project. The funding can be cost reimbursable in which case a contract between the university and the company will be required. Alternatively, the funding can be fixed cost where the company provides a fixed amount to the university to cover the expenses associated with the project. When a contract is negotiated, the normal costs such as faculty and staff time can be included either directly or indirectly. Typically, the contract vehicle is less desirable for the company because it does increase project costs considerably. Furthermore, a contract may be more suitable when both graduate and undergraduates students are involved in the project.
4. Completely university funded. Although rare, in some cases especially with projects that are supported through federal funding, the University may fund the project in its entirety as a result of external funding. One recent example was funding provided by the EPA to work with a company on the design and construction of a fish hatchery powered by alternative energy sources. In this case, the design faculty wrote the proposal to the EPA specifically for support of a capstone design project while partnering with the industry sponsor. The University may also fund some competition projects such as the Society of Automotive Engineers' mini-baja design competition. The University can also raise the project funds through gifts and/or endowments.

Focal

At the start of any industry-sponsored project, a mentor must be identified at the company who is intimately familiar with the project. In many cases, the industry mentor is an engineer who has previously or currently works on the project and has in-depth knowledge of the problem to be solved. The focal is expected to be the main point of contact with the design team and a mentor.

Conclusions

Capstone design projects are complex by their very nature. Open-ended industry-sponsored design problems have many plausible solutions and therefore present an infinite number of ways that a project could produce a successful design. Developing a framework for the industry-sponsored design project is a critical component of implementing a successful capstone design course. Consistent and mutually agreed upon expectations among all participants in the project, industry, students and faculty mentors are critical to a project's success. Last, a funding model that is clearly articulated and again consistent from one company to the next, and from one year to the next is another means to guarantee industry-sponsored capstone design success.

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