Working with Industry Partners on Capstone Design

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This paper reports on development, implementation, and adoption of best practices in working with industry partners on capstone design projects at the University of Rhode Island (URI) during 2007-2016. Rethinking and reengineering of the approach and pedagogy in mechanical engineering capstone design since 2007 provided an opportunity for us to develop new approaches in methods and pedagogy for the major design experience sequence. The senior capstone design is a year-long sequence. A list of best practices and methods is presented that we have created or adopted based on review of best practices in the literature, peer surveys, and our own experience are presented. The process for approaching industry projects is described including a summary of approaches that work well and those that do not. The importance of project funding and several working models for it are presented.

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Background

Since the adoption of the senior capstone design experience by ABET, Inc. in 1996 under Engineering Criteria 2000 (EC 2000)[1,2] there has been significant changes to the curricula of engineering programs. A number of methods of practice have been developed, tried, and reported in the literature. [3-10] In particular, the work of Howe and Wilbarger[11] is extremely useful in identifying capstone design implementation patterns and some of the best practices.

At the University of Rhode Island, we began a complete redesign of our mechanical engineering capstone design courses in 2007. We developed a holistic approach based on the best practices we found in the literature, survey of other engineering programs, and our own experience of more than 30 years of teaching and a set of rubrics for assessment of the design teams and projects. In this paper we report the best practices in working with industry projects that we have found to be useful in our experience.

The development of a consistent and well-documented framework for industry projects is very important to the accreditation process. These projects also affect our assessment methods. Assessment rubrics are also important in teaching and communicating the complex process of design project assessment to the student teams. Student teams are better equipped to respond to the demands of the capstone experience when they have an understanding of the evaluation metrics for their projects.

Variations of the Capstone Design Sequence

In our research and review of literature, we found that capstone design courses come in many flavors and varieties at different institutions. Each institution has adopted their own customized version of the capstone design experience[11] with some of the following notable variations:

- Total semester equivalent credits vary from 3 to 6
- Total duration of time varies from one semester/quarter to one calendar year
- The students may be from a single major or multiple majors in the teams (multidisciplinary within the major to trans-disciplinary)
- One or more professors may be teaching or coordinating the course
- Project definitions may come from industry, state government, federal government agencies, design competitions, research projects, or the instructor
- Projects may be funded internally, externally, or unfunded
- Project space and access to laboratories is generally provided to the students
- Field trips to engineering companies or laboratories may or may not be required by the course/instructor
- Scope of projects and experience is affected by other factors depending on the customs, traditions, priorities, and policies of the institution
- Formal design instruction/lecture may or may not be part of the course; a textbook may be or may not be required
- Project management techniques (using software tools) may or may not be used

All of these factors affect the assessment specifics and the rubrics that may be developed for the specific capstone design course(s). In developing the mechanical engineering capstone design sequence at the University of Rhode Island, we adopted the following features for our curriculum:

- Two-semester, three-credit design sequence (one academic year starting in September and ending in May)
- Students were initially only mechanical engineering but we have experimented with including business and industrial engineering students in the design teams; class size has been 40-72 students
- Two professors team-teach/coordinate the course
- Projects are sponsored by industry, research projects, or national design competitions
- Majority of the projects are industry-funded/ sponsored; very few are internally-sponsored/ funded
- We created an engineering design studio space for the teams (range of 8 to 14 teams of 4-6 students)
- Field trips to local engineering companies is required for industry sponsored projects
- A text is required for the course[12]
- Project plan and progress must be managed and tracked with software tools

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). 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.

Summer (May-August)

- Meet with industry partners to identify suitable projects
- Work through the usually long lists of projects proposed to find appropriate scope, technical difficulty, and size
- Make sure projects are open ended, have not been solved before, and the company does not have a specific solution or path for the project
- Select projects to be presented
- Identify industry technical points of contact
- Schedule presentations for first or second day of class in the fall

Fall semester

- Project presentation by industry sponsors to the capstone class
- Collect student surveys, resumes, and applications for projects
- Define the problem
- Develop design specifications
- Plan and manage the project
- Research possible solutions or supporting information
- Generate concepts (minimum of 30 per student)
- 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)
- Create a proof of concept design
- 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 sponsored project teams must create 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 administrative costs at the university. Faculty and staff time may be compensated indirectly. However, indirect expenses can be covered through administrative costs. 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 NSF to work on research for design of a "Lab-on-a-chip" device. In this case, the faculty wrote the proposal to the NSF and the capstone design project was created to support undergraduates that were working on the research project. The University may also fund some competition projects such as the Society of Automotive Engineers' 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. Sometimes the focal may be a graduate of our program who has been working for the company for a few years but is intimately familiar with the capstone design projects and process at the university. Such projects usually are the most successful and rewarding for the students and the company.

Project Meetings and Interactions

The student project teams are taught and expected to behave like an engineering team. The regularly update and track their project progress using a project management tool. They produce agenda for their meetings. Take minutes of their meetings. Write progress reports and communicate with their sponsors by e-mail, phone, and in person meeting throughout the course of their projects.

Project sponsors are invited to all formal student presentations (total of four throughout the year).

A capstone design showcase is held at the end of the spring semester which is open to all. Students showcase their designs and present their work in a poster format. Students in earlier classes (juniors and sophomores), faculty, industry partners, university administrators, and others are invited to interact with the student teams and learn about the accomplishments of the teams.

At the end of each year, in April-May time, a final wrap up meeting is held with the student team, company management, focal, and professor. The full design is reviewed which usually includes a demonstration of the prototype design.

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 program. 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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