The Benefits of Industry Involvement in the Multidisciplinary Capstone Design Course at Marquette University

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Opportunities for industry involvement in capstone design courses go beyond industry sponsorship of capstone design projects. Representatives from industry can serve as guest lecturers, curriculum advisors, and design project sponsors and team mentors. For the last twelve years industry participation has been a core part of the capstone design course at Marquette University. Practicing engineers provide a relevant, practical real-world perspective of their topic, reinforcing its importance to professional engineering practice. Students (and course faculty) benefit from the up-to-date treatment of the topic provided by guest speakers from industry who have expertise in the topic and are willing to share their experiences with students. Students benefit from industry sponsorship of senior design projects through the opportunity to work on real-world problems of importance to industry, exposure to industry and company-specific project management and product development processes, and familiarity with economic, legal, and regulatory design constraints.

This paper provides a brief description of the Multidisciplinary Capstone Design course at Marquette University, examples of industry involvement in the course, and the observed benefits to students, the university, and industry participants.

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Introduction

Most capstone design programs involve industry in some way. The most common form of involvement may be through industry sponsorship of design projects, which often includes mentorship and funding of projects and project teams. According to a 2005 study of capstone design courses in the United States, 71% of the courses included industry-sponsored projects. The average level of industry funding per project from industrial sponsors varied within individual programs. Many projects received less than $500 per project (48%), and 12% received more than $5000 for at least one project.[1]

Accreditation of undergraduate engineering programs requires a "meaningful design experience" along with a focus on meeting customer needs. Many programs recognize the value of industry partners in the capstone design course in preparing students for careers in engineering and other technical fields. Farr, et. al. (2001) stated "relevant, industry-partnered design is an important part of the undergraduate education experience for tomorrow's engineers".[2]

Capstone Design at Marquette University

The multidisciplinary capstone design course at Marquette University includes biomedical, electrical, computer, and mechanical engineering, computer science, and information technology students. Five faculty members from three colleges within the University representing each of the disciplines involved teach the course over two semesters. In the fall semester information technology (IT) students participate and in the spring semester industrial design students from the Milwaukee Institute of Art and Design collaborate with six of the project teams.[3,4]

Course enrollment is around 180 students in two sections. The course meets twice a week for lectures on various topics important to student projects and professional engineering practice. The focus of the course is on the design project of which there are typically thirty-five project teams consisting of three to six students from the mix of disciplines enrolled in the course. Project teams are formed according to student choices subject to constraints such as co-op schedules, required expertise and skills, and team size. Approximately half of the projects are industry sponsored, with some proposed by students, some by faculty, and others requested on behalf of clients with disabilities.

The course schedule and required team deliverables are based on the design control requirements of ISO 9001 and reflect the design process used in industry. Required team deliverables include the Project Definition, Customer Needs/Target Specifications Document, Generated/Final Concepts Document, Formal Proposal,

Prototype/Mock-Up, Project Notebook, Oral Proposal, and Peer Review in the fall semester. A Project Schedule/Risk Analysis, Experimental Validation Document, Prototype, Project Notebook, Peer Review, Oral Report, and Final Report are required during the spring semester.

Team performance is assessed through team deliverables. Individual student performance is assessed through online quizzes, class participation, attendance, and peer reviews.

Industry Involvement at Marquette University

Representatives from industry participate in the multidisciplinary capstone design course as guest lecturers, curriculum advisors, and design project sponsors and team mentors. This collaboration provides many benefits to students and industry participants.

Marquette University has benefitted from industry involvement in capstone design courses through the building of relationships with industry (which has led to research collaborations and grants), maintenance of a high quality senior design course and project experience, and addition of resources available to students to complete their design projects.[4]

Guest Lecturers

As guest lecturers, practicing engineers and other technical professionals provide a relevant, practical real-world perspective of their topic, reinforcing its importance to professional engineering practice. Students (and course faculty) benefit from the up-to-date treatment of the topic provided by guest speakers from industry who have expertise in the topic and are willing to share their experiences with students. Serving as a guest lecturer is considered an honor and is viewed by many employers as a professional development activity. In our capstone design course, guest speakers from industry present almost half of the lectures. All industry speakers are sent a set of guidelines to follow when preparing their presentations. These guidelines ask speakers to present a general overview of their topic including examples of applications, make students aware of the importance of their topic to professional practice, and address the applicability of the topic to all engineering disciplines represented in the classroom, not just one. Topics addressed by guest speakers from industry include project management, patents, teamwork, human factors in design, green design, software validation, globalization, risk management, and personal and professional liability. Speakers are encouraged to incorporate active learning components into their lectures such as in-class activities and classroom demonstrations to increase the level of student engagement.

Curriculum Advisors

Feedback from engineers working in industry can be very helpful in ensuring that the content and objectives of the capstone design course are up-to-date and relevant to the practice of engineering and other technical disciplines, and are helping to prepare students for careers in these areas. A periodic review of course objectives, lecture topics, and required course deliverables by members of an industrial advisory committee can help fine-tune the course curriculum. At Marquette University, two of the participating engineering departments (biomedical and mechanical engineering) hold meetings with their respective Industrial Advisory Boards (IAB) during which feedback on the capstone design course is solicited. For example, at a recent IAB meeting industry representatives confirmed the value of aligning capstone course deliverables with design control requirements contained in ISO 9001. This helps course instructors maintain a course curriculum that better prepares students for work in industry.

In past years, students participated in a college-wide poster competition at the end of the two-semester capstone design sequence. A few members from the Milwaukee area chapter of the College of Engineering Alumni Association served as judges along with faculty to provide an industry perspective to the judging process.

Industry Sponsors and Mentors

Industry sponsors are required to identify a company representative to act as an advisor to the project. The industry advisor acts as the company contact for the team, and is required to be available to advise teams on issues involving customer needs, provide technical expertise and advice, and approve design concepts and prototypes. Faculty advisors are responsible for administrative issues (grading, monitoring progress of teams, dealing with personnel issues, etc.) and providing guidance to the team. Communication between the team and the industry advisor can be in person or by telephone, e-mail, or videoconferencing. The industry advisor determines the frequency of communication with the team as well as the need for travel.

At the start of the course, we assign a team of students to each project for two semesters. Our senior design teams are required to construct and test prototypes to verify that their design solves the sponsors' problems and meets the sponsors' needs. Students typically have access to the university's computer network, libraries, machine shops, and laboratories. Construction of functional prototypes can be costly and testing of prototypes may require specialized test equipment or software not available to students. Depending upon the complexity of the design and the requirements of the sponsoring company, some prototypes can be made of parts ob-

tained from local hardware stores and easily assembled in a dormitory room or laboratory. Other prototypes may require access to a machine shop for lathes, mills, drill presses, etc., or must be made of materials that require casting, molding, or other processes that might not be available to students in an academic setting. In these situations, industry sponsors are requested to provide the necessary resources (prototyping facilities and/or personnel, laboratories and test equipment) for the project team to complete their projects. We require sponsors to provide the financial and technical resources necessary for the team to complete their projects, as needed.

At the end of the course, industry sponsors are invited to attend final oral presentations. Often, they are asked to help grade the oral presentation as well as the overall project result. Final deliverables such as prototypes, final reports, and project notebooks are transferred to the industry sponsor.

Grading of course deliverables follows the industry model based on objectives and expected performance typically used in performance reviews. Guidelines and grading rubrics for each team deliverable are presented to students during the first week of class and define the expected levels of performance for each team deliverable. Meeting expectations earns a score of 85. Exceeding expectations can earn a higher score, and failing to meet expectations warrants a lower score. This grading model reflects how performance is evaluated in industry and prepares students for how their performance will be evaluated by employers.

Benefits of Industry Sponsorship

Industry sponsorship of senior design projects is beneficial to the sponsoring companies, the university, and students. Industry sponsors benefit by receiving additional technical resources dedicated towards solving a technical problem, at little or no cost. At Marquette University, industry sponsors are only asked to cover all project expenses incurred by students during the course. This might include assistance in building prototypes or providing access to test equipment.

Industry sponsorship can be beneficial to companies with limited technical resources and can allow companies to make progress on lower priority projects without diluting their in-house resources allocated to higher priority projects. It also provides resources to student teams that might not be available in our laboratories. Project sponsorship allows companies to participate in the training of new engineers, advertise their companies on campus, and gain access to a pool of graduating engineers for recruitment.

Students benefit from industry sponsorship of senior design projects through the opportunity to work on real-world problems of importance to industry, exposure to industry and company-specific project management and product development processes, and familiarity with economic, legal, and regulatory design constraints. Capstone design project experiences can sometimes lead to full-time employment for students with the sponsoring company after graduation.

Challenges with Industry Sponsorship

Industry sponsored projects present challenges regarding intellectual property. At Marquette University, students own their intellectual property and can voluntarily sign nondisclosure and patent assignment agreements with sponsoring companies as a condition for sponsorship. Each year, a few of our sponsoring companies do not allow any public disclosure (classroom presentation) of the results of the projects they sponsor. These requests for confidentiality are accommodated through private team presentations to one of the course instructors and the faculty project advisor, both of who have signed nondisclosure agreements with the sponsor.

Typical problems with industry sponsored projects include company contacts not being available to teams when needed, industry sponsors changing scope of the project once the project is defined, unrealistic expectations as to the amount of work and level of quality that a project team is capable of delivering in two semesters, and sponsor expectations that do not match with the course requirements (time, scope of projects, order of steps in design process, etc.).

Recommendations

The collective experiences of the authors with the two-semester multidisciplinary capstone design course at Marquette University has shown that certain types of projects are best suited for industry sponsorship. We have found the following to meet the needs of industry sponsors and students, as well as the requirements of our course:

- Lower priority projects for which the company lacks resources. This is attractive to start-up companies with few technical resources.
- Projects that can be completed in eight months or less (required for a two-semester design course sequence)
- Projects involving the development of new products (may be difficult to complete in two semesters), improvements to existing products (new features, revised packaging, new materials, etc.), or process improvements.
- Projects requiring the development of test procedures and the design of test equipment.

When soliciting potential industry sponsors, we recommend the following:

- Discuss funding expectations with sponsors. Will they reimburse for team expenses or provide an account from which to pay for needed items?
- Discuss goals, timetable, and required deliverables of the course. Sponsors need to understand the learning goals of the course, what the course deliverables are, and when they are due.
- Sponsors need to understand their roles in the project. They need to be available to students for background information, guidance, and design feedback when students need them to be able to meet course deadlines. Sponsors must be aware of required time commitments and students need to respect the time of their industry sponsors. Sponsors and students should agree on the frequency of meetings and decide if travel is necessary.
- Manage sponsor expectations. Do not allow 1) scope changes that will require additional time and possibly delay completion of the project beyond the end of the course, 2) sponsors to require additional deliverables beyond what is required by the course, or 3) sponsors to require students to complete the project prior to the end of the course.

When considering the use of guest speakers from industry, we recommend the following:

- Find people who are good speakers, can engage the students, are experts on their subjects, and can share examples of how their topic is used in engineering and other technical areas.
- Encourage interactive presentations
- Ask speakers to create an awareness of their topic so students understand why the topic is important to professional practice. Speakers should not attempt nor expect to create experts on the topic after one lecture.
- Consider recruiting recent alumni of the capstone design course. Students often relate well to fellow alumni who completed the same course, are close in age to the students, and can discuss how they used what they learned in the course in their careers.

When considering creating an industrial advisory board, we recommend the following:

- Find participants who are good communicators, willing to share ideas.
- Do not make financial contributions a requirement of membership on the board. The purpose of this board should be to collect feedback and advice on how to improve and maintain a relevant, up-to-date curriculum, not on fundraising.
- Make good use of board members' time. Ask specific questions of the board at meetings; get feedback on new programs, ideas, etc.
- Include people with design and project management experience. Try to recruit technical personnel who have "worked in the trenches" and understand what engineers and other technical personnel need to prepare them for professional practice.

Summary

At Marquette University, industry involvement has been a key part of our approach to design education for many years. Our industry partners have served as project sponsors and mentors, guest speakers, and members of industrial advisory boards. They have provided students with experience in solving real-world problems of interest to industry, provided up-to-date presentations of various topics important to professional engineering practice, and helped us maintain a relevant, up-to-date engineering curriculum to best prepare students for careers in engineering.

References

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