Session 2625

Experiences in Capstone Design Projects: Partnerships with Industrial Sponsors

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Abstract

Capstone design projects in the department provide student teams opportunities to create engineering solutions to problems identified and sponsored by industrial partners. A partnership relationship model for achieving engineering education goals, which is initiated between the department and the sponsor during discussions prior to student involvement, is the central theme that forms realizable expectations for student design projects. Experiences from 32 student project design teams over the past three years provide the basis for perspectives and insights on what is important for achieving a successful partnership and how to improve the odds for a successful student design project. Summaries from several actual student projects suggest the scope, depth, and expectations that have yielded success, plus some that haven't been so successful along with diagnostic suggestions as to the cause and how to improve. A table shows the categories of sponsors, design team size, and key design goals for these student projects, plus an assessment of the success and engineering design quality for each project. A brochure is described that was created to concisely convey the partnership concept to prospective sponsors of student design projects. This tool has been very useful to convey quickly and painlessly the partnership expectations and general responsibilities when initially contacting potential industry sponsors. Experience indicates that partnerships with industry sponsors yield meaningful educational experiences for engineering students, allow industry to explore an idea with minimal commitment, create friends for the university, and can lead to permanent employment for students following graduation.

I. Introduction

The Department of Electrical and Computer Engineering at the University of Idaho requires all Electrical and Computer Engineering students in their senior year to take a two-course sequence, Senior Design, which emphasizes applications of engineering design. This fulfills the major design experience listed in the Professional Component of the Engineering Criteria 2000 (EC2000) accreditation requirements. It also helps achieve several of the EC2000 program outcomes statements including an ability "to design and conduct experiments", "to design a system, component, or process to meet desired needs", "to identify, formulate, and solve engineering problems", and "to communicate effectively."

The first 3-credit course in this capstone design sequence, normally taken during the fall semester, introduces students to the design process by first requiring individual students to accomplish two assigned designs which are sufficiently simple that these two projects can be accomplished within six weeks time. These initial projects serve to introduce students to several aspects of engineering design, including understanding of the project objectives, project planning and time schedule estimates, using available resources - time and devices and lab equipment - to create a working solution, and written and oral reports.

Following these introductory individual design projects, the students are then presented with the industry-sponsored projects and choose among the half dozen to dozen projects that are presented. Student design teams are then formed, with guidance from the instructor to ensure reasonable balance and range of capabilities. These same design teams remain intact for the remainder of the fall semester design class and through the spring semester follow-on design class. These "customer oriented" projects are the focus of this paper: how are they selected, what is the relationship between the university and the sponsor, how can experience help select future successful projects, and does this provide students with good engineering design education.

To provide students with practical engineering experience while still meeting course requirements, we seek design projects from industry that students can accomplish. This industry-university collaborative effort is mutually beneficial: project sponsors receive the benefits of the students' efforts, the students work on practical engineering design projects, and course requirements are met. A side benefit is that both the company and the student get a chance to view one another in a “pre-employment” setting, which has lead to permanent employment for students following graduation.

II. How are Projects Identified?

Projects are identified through discussions between the instructor and one or more company technical personnel prior to any involvement with the students. From the beginning, the potential project sponsor is informed about expectations and that this is a partnership between the university and the sponsor for benefiting students in their engineering education. A sponsor of a design project selects a project, in consultation with the course instructor, for the student design team.

Projects must include an emphasis on design rather than being either an assembly project or a research project. Students are to be allowed to make design choices and are required to justify those choices based on engineering principles. An assembly project can be challenging but without design, it fails to meet the course objectives. Some seemingly good projects are actually research projects and, if pursued, require students to develop new sensors or processes rather than create a design. We have found that research-oriented projects generally are not good student design projects since the majority of students' time is spent on researching ideas rather than on engineering design. Sponsors with such needs are not discouraged, but rather encouraged to pursue the research through support for a graduate student.

Student design projects tend to be organized according to the following.

- ♦ 2 to 5 students per project
- ♦ Sponsor for every group project
- ♦ Faculty supervision
- ♦ Sponsor reviews preliminary design
- ♦ Students produce a working prototype
- ♦ Design oriented, using students' creativity
- ♦ Projects can feature either
    - Hardware and/or firmware, or
    - Implementation of a process (e.g., "design a hardware test process")

III. How many students for a project?

Faculty judgment determines the number of students for a specific project, and can vary from two to five or more. Experience has shown that certain types of necessary engineering design increases the number of design team student members. However, having more than necessary contributes strongly to one or more students not being fully involved in actual engineering design.

Some very broad guidelines have evolved for us over the years, which guide us in the determination of the number of students for a given project. If the project is expected to incorporate a microprocessor using student-designed code, that effort alone will consume the effort of at least one student. Signal conditioning and input/output circuitry will need another student member, and packaging, together with an LCD display and indicator lights and printed circuit board layout will require a third student member of the design team.

Creating the layout for a custom printed circuit board (and sending the layout electronically to a commercial pc board fabricator) is a useful educational exercise but is not sufficient for justifying an additional member of the team. We have seen that usually two or more team members will work together for a couple weeks to produce the board layout, and then another week is needed to populate and test the board after it is received back from the commercial fabricator. Thus the work required to create a custom printed circuit board is much less than one student's effort for a semester and that alone does not justify an additional team member.

Some projects that require three or four students have used one student primarily for developing custom code for a programmable device (microprocessor or FPGA or similar device), and two or three students for assistance with algorithm development and designing multiple signal conditioning circuits. For example, interfacing with several different types of sensors can require an investigation of the signal features followed by designing custom signal conditioning for each sensor. Sometimes this effort can be time consuming because of a wide range of operating conditions or challenging noise problems. Such projects may need one additional student than otherwise.

IV. Partnership with Industry

When contacting potential sponsors of design projects, we have found it is important to discuss the relationships among the sponsor, university, and students. We have found potential sponsors to be friendly and enthusiastic, and even when a design project does not evolve from the discussion, there still is a good interchange and understanding. Normally an individual, typically an engineer, is the primary contact person on behalf of the sponsor who is expected to:

- Participate in the engineering education process
- Propose potential student design projects
- Meet with instructor to select project
- Provide for project expenses:
  Parts, direct costs, lab fees
- Give technical assessment feedback

The university instructor is responsible for accomplishing the teaching objectives for the design course, and these objectives include producing students who can:

- Create & implement feasible solutions to engineering problems
- Understand the iterative design process
- Use resources effectively: time, money, parts, lab equipment, information
- Learn "team" skills

V. Additional Responsibilities

Existing laboratory equipment can support some projects that require the use of software development systems. However, some projects require specialty software that is not available in the ECE laboratories. In such cases, this should be identified early – preferably during discussions between the sponsor and university before students are involved – so that arrangements can be made by the sponsor to provide this additional, and sometimes costly, tooling. On some occasions this has caused mutually agreeable changes in the project objectives so as to avoid high cost items.

On a few occasions sponsors have loaned the student design team specialty equipment and software which is used to accomplish the project objectives and then is returned to the sponsor at the conclusion of the project. This can be very useful to allow students to gain access to necessary tools without having to seek additional funding for such items.

VI. Examples of Sponsored Projects

Over the past three years over 35 student design projects have been sponsored by specific customers. Many of these are industry sponsors; others are government agencies and other departments within the University of Idaho. In a very few instances, an individual sponsors a student design project because of personal interest in a particular project.

Listed in Table 1 in Appendix A. are examples from these sponsored projects. A brief project description is given, along with primary challenges of each project, project assessment of performance and degree of success, and key design features, which were selected and implemented by the student design team. Many of the project teams consist of three students – our experience has shown us that this is a good balance between having sufficient workers for a project versus complexities of managing a larger student team.

One project (no. 8 in Table 1) did have five student members and was a successful project; another (no. 9) had 4 members and also was successful for achieving the objectives. However, considerable effort went into project organization for that five-person team, and in fact operated with two sub-projects consisting of two and three person teams, which did interact carefully to achieve the complete overall success of this large project. Although project no. 9 was successful, it did not effectively use all members of the design team. The result was that 2 or 3 of the team members carried the majority of the project work. This was due primarily to the nature of the tasks that were needed – in hindsight, it was really a 3-person project.

VII. Did the projects succeed?

What constitutes success? Is that a successful capstone design experience, or successful course grade, or that the final project "worked", or the company was happy - because of information generated, interaction with students - possible future employees? – or was the customer happy because the project prototype performed satisfactorily?

To answer this question about success, it is appropriate to return to the teaching goals for this design class sequence, which are listed in an earlier section. If students are to learn to create and implement feasible solutions, understand the design process, use resources effectively, and learn team skills, then it would seem that a fully functioning project is not really a necessity but is rather a desired, but not required, outcome. In this sense, some projects that did not actually work completely did indeed provide an excellent design experience, while other projects that were successfully completed only allowed the students a very limited design experience. For example, see projects no. 13 and 18 in Table 1 as candidates for being successful in the operational sense, but lacking sufficient design content for a top-rated design experience.

Many projects were successful both for providing an excellence design experience, including both project management issues and technical design, and also achieved the desired performance goals of a functioning project. Some examples of such projects listed in Table 1 are projects no. 1, 3, 7, 8, 10, 14, 15, 16, 17, and 19.

VIII. What contributes to a successful project?

A primary ingredient is commitment. Commitment is necessary – from the design class instructor, from the department since additional teaching effort is needed for capstone design classes, and from the sponsor or customer to be willing to partner with the university for engineering education and to provide project funding.

Project selection is critically important so that students can have a beneficial design experience and so that customers can benefit from a successfully performing prototype at the conclusion of the design project. Industry sponsors also recognize the benefit of interacting with students, and do benefit from new ideas and fresh insights from eager students. Project selection includes skills to discern between design and research, estimate design team size necessary for a proposed project, and assessing what tools and skill levels are needed to accomplish a potential student design project.

Finding design projects requires much planning and contact with potential sponsors throughout the academic year, so that when students in the design class are ready to begin working on sponsored projects, then there are sponsored projects ready for them. Several faculty can share this time commitment. In our department we have been most recently using a “coordinator” who makes contact with companies and others to identify design projects. Another faculty person is the actual course instructor and has the responsibility of forming student design teams and managing most of the projects. Other arrangements are also valid; however, our experience is that the complete task of finding industry sponsors and teaching the design class is too much for one single individual. Some type of faculty team effort is needed in order to maintain a good flow of successful projects over several years.

IX. Teaching Credit for Faculty

Establishing and implementing appropriate teaching credit for faculty engaged in teaching design project classes is challenging. Design classes take more time than others because of guiding students through creative endeavors, weekly meetings with individual student design teams, and contacts with sponsors. Faculty teaching design project classes receive 50% more teaching credit than for other classes, and faculty serving as project advisors can receive up to 1 credit for that effort. However, receiving 1 additional teaching credit usually never changes the remaining workload. Typically faculty will participate as project advisors because of an interest in the project and the project sponsor.

X. Conclusions

Company contacts and successful student projects can make friends for the university, whereas there is also a risk of alienating some if student’s achievements and project communications are not what are expected. Experience shows that it is very important to discuss realistic expectations and basic management rules with potential sponsors right from the beginning, well before students are involved at all. The relationship between the student design team and the sponsor should not be as a manager-employee, but needs to be like a consultant without day-to-day supervision.

The design project experience for students is excellent under most circumstances. Although some projects won’t completely achieve the project goals, these can be tolerated to some extent while continuing to learn how to improve this industry / university partnership which is excellent engineering education for the students.

JAMES PETERSON
James N. Peterson is a Professor of Electrical Engineering at the University of Idaho, Moscow, ID, where he teaches courses in Design Projects, Digital Filtering, Circuits, and Control Systems, among others. He received his Ph.D. in Electrical Engineering from Iowa State University and worked for six years in industry prior to joining the University of Idaho. Dr. Peterson is a registered professional engineer and is actively involved with student projects with industry as well as conducting research on voice signals and compression algorithms.

APPENDIX A.

Table 1. Student Design Projects and Qualities

Project descriptions	Design Quality Rating	No. of Students in project team	Project Challenges	Project assessment	Key design features And comments
1. Remote hand-held controller for machinery; rf link	3	3	Identifying customer needs – accomplished through initial meetings with customer; finding rf module, which was accomplished successfully	Was successfully demonstrated at customer's manufacturing plant; customer was pleased with performance.	Implemented rf RPC module and safety considerations.
2. Display for existing lab equipment	2	3	Details of signals not well defined initially; needed more instructor / customer work for definition and project needs prior to student involvement.	Only partially worked, and without some desired options for handling offsets and data conversions	Used microprocessor and LCD display
3. Small scale hydro Power System	3	3	On-site assessment necessary - very remote site; power generating constraints due to location	Feasibility study and actual design and hardware testing all were successful; customer well pleased	Required designing layout and devices for power system control panel
4. Musical Digital Interface	1	3	Working with existing 25 year old electronic devices without adequate documentation; too much time consumed on this part	Not successful overall; some intermediate portions worked successfully	Used microprocessor and digital electronics.
5. Low noise design of a Calemetric Sensor	2	3	Ultra-low noise amplifier design is not covered in normal coursework – required considerable learning plus design	Successful operation demonstrated with sensitive amplifiers, but desired a lower noise content.	Specialized amplifier design required additional faculty guidance.
6. Communication chip tester	1	3	Time spent to understand how to operate a complex chip before project could be accomplished	Did not work with all options of data sequences; did work on simple data sets.	Used data switching and careful timing considerations.
7. Lab control system - life sciences	3	3	Understanding the process to be controlled; instrumentation creation	Was successful and provided customer with useful tool.	Used LCD display and microprocessor; has menu of options.
8. Chip verification device	2	5	Many meetings with customer to define options and complex selection methods; project management and organization	Successful – customer please with students accomplishments on such a complex task	Used two microprocessors; excellent design project, but required much faculty input for project org.
9. Remote Lab Operation via web interface	2	4	Learning about web-based data protocols and lab equipment interfaces	Did perform successfully via web interface.	Used web tools for interface; remote start required attention to safety issues – this was good experience.

Table 1. Student Design Projects and Qualities (continued)

10. Monitoring device and display - small data logger	3	3	Technical challenges: battery life, robust microprocessor design	Successfully performed most functions; customer satisfied.	Used microprocessor w/LCD display and custom pc board, and current transducers.
11. Instrumentation noise reduction - spectrometry device	1	3	Difficult to find noise sources and noise characteristics; leans toward research project	Provided customer with additional insight into specialized signal processing; overall not operational	Process design project used DSP schemes; required computer-based data analysis; insufficient design content. .
12. Remote control of audio devices	1	2	Needed clearer project objectives – too many pieces initially created confusion	Not successful due to inefficient design leading to large assembly effort, along with insufficient team commitment	After switching needs were defined, this became an assembly project; insufficient design content.
13. Speech processing from file data	2	2	Needed faster method for transferring data from open file; tended toward research rather than design	Successful for some objectives related to design; research on algorithms was incomplete	Required researching and designing signal processing algorithm; remainder of project implemented design w/ DSP eval. Board.
14. Rapid switching network for Christmas lighting display	3	3	Understanding technology for rapid power line carrier switching	Successfully demonstrated performance	Used power line carrier switching network; successful performance resulted from dedicated students.
15. Vision-based counting of cardboard panels	3	2	Understanding cardboard panel handling; developing counting algorithm from camera line image	Successfully met all objectives	Used line-scan camera as sensor; microprocessor based; displayed real-time performance.
16. Small fan test facility	3	2	Managing interdisciplinary design team w/ 2 EEs and 3 MEs; defining I/O requirements with sufficient lead time	Performed successfully in integrated system with mechanical and electrical features	EE/ME design project; used microprocessor and LCD display.
17. Mechanical stress tester	3	2	Managing interdisciplinary design team – 2 EEs, 2 MEs; needed sufficient lead time for defining electronic objectives.	Performed successfully; needed to be more robust.	Microprocessor based; custom pc board fabricated
18. Grain bin monitor	2+	3	On-site requirements required several trips to customer location to understand operating environment.	Performed successfully; customer satisfied.	Used indicator lights, & switches; safety issues; custom pc board; low level electronic design.
19. Microcontroller I/O board for undergraduate lab	3	2	Need to fully understand multiple options desired by customer before initiating hardware design.	Good design project because of emphasis on performance and not on appearance other than neatness.	Microprocessor design; custom pc board fabrication; multiple interface options.

APPENDIX B.
Portions of Senior Design Project Brochure

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Student Design Projects
in
Electrical & Computer Engineering

Here's a bright idea … for exploring a technical development, or creating a new application …

… partner with a student design team at the University of Idaho.

Senior Design Projects
Department of Electrical Engineering

The Department of Electrical Engineering at the University of Idaho requires all students in their senior year to take a two-course sequence, Senior Design, which emphasizes applications of engineering design. To provide students with practical engineering experience while still meeting course requirements, we seek design projects from industry that students can accomplish. This industry-UI collaborative effort is mutually beneficial: project sponsors receive the benefits of the students' efforts, the students work on practical engineering design projects, and course requirements are met. A side benefit is that both the company and the student get a chance to view one another in a "pre-employment" setting. Projects are identified through discussions between the instructor and one or more company technical personnel.

TEACHING OBJECTIVES

- ♦ Create & implement feasible solutions to engineering problems
- ♦ Understand the iterative design process
- ♦ Use resources effectively: time, money, parts, lab equipment, information
- ♦ Learn "team" skills

GROUP DESIGN PROJECTS

- ♦ 2 to 5 students per project
- ♦ Sponsor for every group project
- ♦ Faculty supervision
- ♦ Sponsor reviews preliminary design
- ♦ Students produce a working prototype
- ♦ Design-oriented, using students' creativity
- ♦ Projects can feature either
  - hardware and/or firmware, or
  - implementation of a process (e.g., "design a hardware test process")

APPENDIX B.
Portions of Senior Design Project Brochure (continued)

PROJECT CRITERIA

- Design content (class requirement)
- Beneficial to customer
- Time constraints (~12 hours per week)
- Must fit into semester time frame
- No proprietary or critical-path projects
- Limited by available resources
- UI engineering facilities used by students

SPONSOR'S ROLE

- Participate in engineering education process
- Identify potential student design projects
- Meet with instructor to select project
- Provide for project expenses:
  parts, direct costs, lab fees
- Give technical assessment feedback

TYPICAL PROJECT PHASES

- Discussions between Company and UI
- Identify potential student project
- Company description of desired project
- Student design group formed
  - clear design objectives
  - understanding of desired results
- Student-generated formal proposal
- Regular student progress meetings
- Development, construction, and testing
- Student reports: written, oral, and poster
- Final product to customer

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