Defining Industry Sponsored Capstone Projects

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There are only three hard and fast rules for a Capstone project in the Electrical and Computer Engineering programs at the University of Oklahoma: The industry partner must 1) Have a definite need for the product, 2) Assign a Mentor who can guide and critically review the students' design, and 3) Provide funds for two student teams to design, fabricate, test, and document their implementation of a product that meets the customer's needs within time and negotiated budget constraints. Because our Capstone class is taken by both Computer Engineers and Electrical Engineers, we are able to support projects that variously mix hardware and software technologies. This paper discusses the underlying construct of projects that have proven to be successful over the past thirty-two semesters and what we have learned to avoid from some not-so-successful variants.

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Course Background

Definition of a successful Capstone project depends heavily on the environment in which it is to be executed. Capstone design in the Electrical Engineering and Computer Engineering Programs at the University of Oklahoma (OU/ECE) is a one-semester course. The students are assigned to two teams of four or five students to independently work on each design project. The course typically has an enrollment of between 15 and 50 students. Students from both the computer engineering program and the electrical engineering program take the capstone design course in their senior year. As reported in the 2008 conference, the Capstone program at OU/ECE depends heavily on having two to five industry sponsored projects each semester[1]. Projects are provided by private industries, government agencies, and faculty (occasionally from other university departments). Each sponsoring organization provides a one or two page Statement of Need, a mentor that is responsible to act as a single point of contact for design information, and funding to develop the product. Mentors provide project requirements, attend design reviews, and participate in the evaluation of their assigned students at the end of the project. The students are expected to provide weekly activity reports, conduct a preliminary design review (PDR), a critical design review (CDR), and a final project presentation. The "project" is thus the result of an up to 24-week dialogue between the Sponsor, the Instructor and a 16-week Student design experience: all focused on meeting a specific customer need.

Choosing Industry Partners

The prime objective of the Capstone project is to provide the students with an experience that challenges them, that gives them a chance to demonstrate the ability to learn, and that can reward them with the opportunity to identify and affect a design solution to a customer's need.

A successful capstone design project begins by choosing to work with a suitable sponsor. In the OU/ECE programs, we choose to work with sponsors who have three attributes: a project that represents a genuine need for their organization, a person who benefits from meeting the need who will act as a mentor, and funding to purchase the parts necessary to complete the project. Sponsoring agencies can include large and small businesses, government agencies and university entities. Generally, electrical and computer engineers who can serve as mentors are in the industry partner's employ.

Students are enthusiastic and engaged when they know their capstone design project will be used by the industry partner[2]. Even if the project will be modified before being used in the sponsor's application, the students appreciate that they have contributed to the success of the industry partner and feel that their work is important. Choosing a project that is a real need for the industry partner can also keep the project mentor motivated because often the project is one that the mentor has wanted to accomplish and now can with the resources of the capstone design team.

The mentor is a critical part of our capstone design process. Choosing an industry partner that will assign a competent mentor and give the mentor the

resources (especially in terms of time) to nurture the project is fundamental to the project's success. The mentor acts as a single point of contact for the students working on the capstone design project providing design information and project requirements[3]. The mentor must be familiar with the technical details of the project and the system in which the project is expected to operate because the mentor is expected to review the design and provide meaningful feedback. The mentor writes the Statement of Need (SoN), which defines the customer need and acts as the starting point for the design teams. The mentor is also expected to attend all design reviews and, of course, the final presentation.

A suitable industry partner will be able to provide the resources necessary to complete the project. This usually include parts used to construct the system, necessary software (if not already available to the team), access to technical documents, and sometimes access to testing facilities or equipment that the project is expected to interface with. If the project is required to interface with an existing device, it is helpful for the industry partner to loan the existing device to the capstone design team. If the device is too large (for example, a radar transmitter), then the mentor can arrange for the capstone design team to visit the installation to take measurements or perform verification testing.

Six to eight weeks before the start of a new semester, the capstone instructor sends letters out to all of the potential industry partners. One of the purposes of the letter is to spell out precisely what will be required to support the project. It lists the dates of all design reviews so that potential mentors can verify their availability. It spells out the resources that are expected from the industry partner. If the industry partner is interested in sponsoring a capstone design project, the letter asks them to compose a Statement of Need that defines the project requirements and identifies the Mentor at least two weeks prior to the start of the semester.

The Instructor works with the Mentor to refine the SoN to assure clarity in expressing the problem, stating performance expectations, the environment in which the product will operate, and Standards to be incorporated into the design. The final SoN must be ready for posting and discussion on the first day of classes, at which students will be given an opportunity to bid on projects to which they prefer to be assigned for the upcoming semester.

Choosing Appropriate Projects

An appropriate project for the OU/ECE capstone design program has a clear Statement of Need, represents a concrete operational need, requires skills developed by our curriculum, and has a schedule that is compatible with the course schedule. The ECE Capstone Experience is designed to foster a discovery and review process that combines the skills of the student teams and the experience of the Mentor to hone the final form of the end product.

The Statement of Need is a one or two page document that describes the industry partner's need in enough detail that the design team can understand it. It is also important for the capstone instructor to understand the partner's need so that students with the appropriate skills can be assigned to the project. The Statement of Need is not a set of requirements; requirements will be discovered through negotiation and dialogue between the sponsor and the design teams. Projects that are poorly conceived or vague from the start are not likely to be successful[4].

Our capstone design program is multidisciplinary in that we have students from both our electrical engineering program and our computer engineering program in the course. Appropriate projects would include an extension of skills that we expect our students to have learned in their respective programs. It is even better if the project deals with technology that one of the ECE faculty has experience with so that faculty member can act as a technical advisor to the team.

Since the capstone design course is a university course, it starts on a particular day and ends on a particular day. The course is scheduled so that the preliminary design review (PDR), the critical design review (CDR), and the final presentations happen on specified weeks. We have found that this is necessary to maintain an orderly course structure. The project cannot have any constraints that interfere with the course structure. For example, a mentor who could not begin until four weeks into the course would be a significant setback to the teams assigned to that project.

The class structure includes a review process that allows the design to mature during the course of the semester. The dialogue between the students, the mentor, and the instructor, at and between these reviews are intended to focus the students' ideas and energies on an increasingly detailed, compliant design. The first four weeks of research result in a functional design approach, a project schedule and a budget recommendation that are presented at the Preliminary Design Review (PDR) and documented in a draft report. Budget authorization and Action Items (AIs) from that review lead to a detailed design, which is presented at Critical Design Review (CDR) with a request for authorization to spend. This may include changes imposed to differentiate between approaches proposed by respective teams.

The need for a product to solve a specific customer need remains fixed throughout the project although the design may change to reflect new discoveries and dialogue between the Mentor and design teams. The Requirement is a statement of the minimum characteristics of a product to meet that need. Some end product performance parameters may be stated as goals in the Statement of Need. The review process allows each student team to formulate a design alternative that meets the need and which incorporates additional desired features as negotiated with the Mentor by an established review process. Product features and performance characteristics are locked in at the Critical Design Review.

Developing Student Teams

Once a pool of appropriate projects has been chosen, student teams are assigned to the projects. Successful student teams have the right number of people with the right skills, each of whom has a defined role on the team.

In our capstone design program, we assign two design teams to each project. Each design team has four students. Assigning two teams lets the industry partner interact with eight students which is important because a motivating factor for many industry partners is to evaluate the students for future hires[5]. The industry partner also gets to see two solutions to their project and then choose the one they believe is the best.

Ideally, each team has four people. It is unlikely, however, that the course enrollment is an integer multiple of eight. In our experience, it is better for teams to have five persons as opposed to three. It is critical that each team member has a defined role that the student can be held accountable to because in our experience, shared responsibility results in failure. Our typical roles are project manager, configuration manager, financial manager, and documentation manager. Each role has a defined set of activities that the student holding that role is expected to perform. Students on each team decide which member will fulfill each role.

In our capstone design course, we publish the Statement of Need for each project during the first week so the students can view them. Students then select which projects they are most interested in, giving a first, second, and third preference. We use each student's resume (writing a resume is their first week's assignment) and their indicated preferences to make team assignments. We try to maintain an appropriate mix of computer engineers and electrical engineers for each project, depending on the project requirements. It is important to include any skills that a student might have acquired outside the university, for example at an internship or the military, in the assignment process.

Attributes of Successful Projects

Attributes of successful projects include:

- Direct application: An application to which the student product can be immediately put to use.
- Limited Scope: The scope of the problem must allow sufficient time for research, formation of alternative solutions, and documentation of the design at critical stages.
- Sufficient funds: Authorized funds for the projects should be sufficient to allow the mentor to take some risks that differentiate the teams. Funding expectations are set at kick-off, budgets are set after Preliminary Design Reviews. Change notes can be made via purchase authorizations made at CDR.
- A committed mentor: A mentor who is willing to challenge the students and who can help them make quick decisions to take, but yet manage, risk.
- Design breadth: The product should include components that challenge the skills of both EE and CpE Student members; Student teams ideally will be composed of both EE and CpE Students and projects should offer that breadth.

It is then up to the instructor to assign two competitive project teams to each project with a balance of experience and academic accomplishment (GPA, student society, leadership and other attributes) .

Project Attributes to Avoid

Unsuccessful programs generally succumb to one of the following maladies:

- Over-Specification: When the Statement of Need focuses on how the product is to be developed rather than what it is to accomplish.
- Time-Crunch: Product timelines that are driven by a need to 'get to market' are less viable than those that focus on meeting an 'operational' need. Benefits of having the latter product are always welcomed while benefits of the former kind have a high temporal time constant.
- Technology mismatch: It is not necessary that the students have direct experience with the components or processes required to affect the design. However it is best if the technology matches the expertise of our faculty so that they can provide the students with on-campus touchstones to help guide them to the resources needed to answer their research and design questions. ECE Faculty members, Instructing

Staff and Graduate Students are all willing to serve this valued function.

- Student-Mentor Communication problems: This can happen when mentors become distracted or drawn away from the projects or when students do not take the initiative to approach the mentor to help with decisions.

Conclusion

A successful capstone design project requires a committed industry partner, a concrete operational need, the right mix of students with the right skills, and a well defined course process. We have outlined project elements that can be used to determine upfront whether a proposed project is likely to result in a successful project and a method to assure the semester-long student product meets the customers need.

References

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