Competition in Senior Design Projects

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Abstract - *This paper describes how learning is enhanced during senior engineering design projects when market-place constraints such as competition, limited resources, and administration are added to the assignment. Many engineering programs focus on merely completion of senior design projects; however, senior projects benefit from market-place constraints because students are exposed to real-world conditions and encouraged to focus on simple, inexpensive, and robust designs. The role of the instructor and student perceptions are discussed as we explore the advantages and disadvantages of using competition in senior design projects. Several types of competitive projects have been completed by seniors in the Electrical Engineering Department at the Air Force Academy. We discuss the goals and requirements for these projects and offer ideas for many other feasible design projects. Finally, student system integration issues such as scheduling, manpower, and cost are considered in light of competition. While the possibility of a "win at all cost" mentality is a disadvantage, the real-world experience gained through competition promotes better understanding of subject material by all students.*

1 Introduction

The Department of Electrical Engineering at the United States Air Force Academy has tried several different competitive senior design projects with great success. One of the overriding reasons for the success of these design projects is the competition itself. The most recent competitive project was a basic remote control car chassis which was required to autonomously follow a strip of electrical tape placed on the floor in some random pattern. This Autonomous Line Following (ALF) vehicle could be controlled using any electronic equipment the students could design and install on the chassis. Various types of competitive projects have advantages over noncompetitive projects; however, the remote control car chassises have a somewhat unique advantage since they can be stripped of the student-designed electronics and used in subsequent semesters.

2 Advantages of Competition

There are two categories of competition advantages in senior design projects. First, there are the actual learning benefits not realized with an individually completed design project. An individually designed project does not have to be "better" than another project. Second, there are the motivational benefits of competition which provide the atmosphere to enhance learning. A student motivated by competition performs better and learns more than a student merely working toward "completion" of a project.

The learning benefits obtained by using competition include: working in a real world environment with market place constraints to encourage good, practical design practices; and, learning from other students who are working on the same project. In the real world, a poorly designed product will not stay on the market very long. Consequently, why not allow students to feel the pressure of designing a product which is competitive with their fellow student's projects? This pressure encourages the students to focus on simple, inexpensive, and robust designs that work. In addition to the real world environment, learning is enhanced through competition when the students learn from each other. Some of the most productive learning was accomplished during the final briefings that each competing student team presented. The other students were very interested in the design approach used by the other teams. Even the winning team learned several things which might have improved their car design.

Motivation to work hard on the projects was a significant advantage supplied through competition. The students took pride in their work if they could be competitive, beat the other teams, or even triumph over the instructor's car. The students were also motivated by an absolute measure of success. There was no question which ALF car had the best design when the simplest design had the fastest time on the test track. The students were motivated by each other to go beyond mere completion of a prototype which fulfilled the minimum design requirements. The students wanted to be the best!

3 Disadvantages of Competition

The disadvantages of competition were relatively minor compared to the advantages. There is more administration coupled to the coordination of a competitive design project. Another disadvantage is the failure of students to see the big picture when competition is involved. A particular problem occurred when one design team was so intent on winning that their design became cumbersome and dysfunctional. On the other hand, even this can be thought of as an advantage because the students learned a great deal while trying to make their inappropriate design work. Finally, there was less student interaction outside of the student design teams. Students who would normally discuss design ideas together were more secretive with their approaches because they thought they would lose a competitive advantage.

4 Role of Instructors

The use of competition in senior design projects provides unique opportunities and challenges for faculty members. Perhaps more than in non-competitive projects, it is vital that the faculty be deeply involved in project preparation. The design challenge must be carefully defined and scoped to ensure that the fundamental requirements can be met in the time allotted, while providing opportunity for incremental improvement as teams compete. Adequate parts must be procured for the total anticipated need. Most importantly, we have achieved the best results when faculty teams participate in the competition. In most cases this means that a faculty team develops the problem description, and implements a physical design in the semester before it is assigned to the students. There are three major benefits to this faculty involvement. First, during the faculty design phase, the problem statement can be refined, and general component requirements can be determined and planned for. Second, members of the faculty team become intimately knowledgeable of the problem, allowing them to be effective mentors to the student teams. Finally, the participation of a faculty team provides a real boost of motivation for the student teams. Many student teams set a goal to beat not only their fellow students but the faculty team as well (in one case they succeeded!).

While participation in the design competition requires considerable faculty resources, there are compensating benefits. For example, a two-member faculty team can develop a project which is subsequently assigned to eight two-member student teams. Furthermore, the resulting hardware can often be used to demonstrate design concepts in a variety of courses. In fact, a graduate from our electrical engineering program returned to discuss his ALF car design with students enrolled in a basic electrical engineering course. Finally, a senior design concept deemed successful can be used in future semesters as well, with minimal additional faculty preparation.

The interaction between faculty members on students is important during the student design phase, as well. Drawing on the lessons learned from their own design experience, faculty are better prepared to play the role of mentor to their student teams. They are also well positioned to function as "cheerleaders" to motivate and coax the best from the students. In our experience, the motivation provided by competition and faculty involvement generally result in exceptional student performance.

5 Project Administration (Manpower, Cost, Schedule, Integration)

At the US Air Force Academy, the senior design class is offered during the Spring semester. Course planning begins in early September the semester before. Planning begins with project descriptions provided by each faculty member within the department. The requirements description includes a short paragraph describing the project, necessary student prerequisites, and the number of students allowed to work on the project. Project budgets are normally limited to $100 per project. The project descriptions are compiled by the Senior Design course director and issued to the students in early October. Students choose their projects by the end of October. Students are required to meet with their project mentors beginning in November to further discuss project requirements and order any specialized components. Students are encouraged to complete a small portion of their project as their final design assignment in their Fall senior laboratory course.

The Senior Design class begins the first week of January. Students are assigned a variety of project related tasks due during the course of the semester. These include: a formal student-written requirements definition, a schedule containing key project milestones, an initial paper design including circuit simulation if appropriate, a final design with working prototype, a technical report, and a final oral presentation.

The key to successful student completion of the project by semester's end is establishment of a detailed scheduled with well-thought milestones. The schedule provides a roadmap for project completion from project requirements definition through project delivery. Students are required to use a scheduling program such as Microsoft Project. Student's are graded on their adherence to the schedule and successful completion of established milestones.

6 Student Perceptions

A student's impressions concerning a course are often a good indicator of what was actually learned during the semester. Positive impressions about a course (it was fun, the problem was interesting) generally indicate that high-level, cognitive learning took place. When students have a negative attitude about a class, it often indicates that the objectives of the class were not met. In this course, student perceptions were gathered through informal interviews that were conducted after the course was completed.

The student's impressions of the design competition were overwhelmingly positive. Students reported that they were intrigued by the idea of using their engineering knowledge to actually build a novel and interesting project. Laboratory work is typically enjoyable for students and in this case the competition aspect was seen as bringing a sense of realism to the project. The task was considered to be at an appropriate level of difficulty for senior electrical engineering majors. Feedback from the students indicates that the problem was challenging yet not so difficult that they were forced to constantly rely on instructors for direction. This level of difficulty also fostered "team building" within the groups. Brainstorming, colleague-level critiques of designs through interaction and out-briefings, and responsibility for accomplishing a task were perceived by the students as valuable "real life" lessons.

Competition between designs, including the instructor design, was seen as a significant motivation factor. Continuous refinement of the design was an important part of the learning process. The "Open House" night, when the cars were actually raced in front of other students and faculty, provided additional motivation for success. The students pushed each other to create designs that were "the best" and not simply "good enough to get by." One student's assessment of the course was that "...it really validated my education. [The course] proved that I actually did learn something after studying EE for five semesters!"

The negative student feedback was limited to the concern by some students that the project was too time consuming. One group of students worked an excessive amount of time on their project. The underlying cause was over-design. Even in this case, the students acknowledged that they learned the real-world danger of over-thinking a design. This design-team produced an unsuccessful design but conceded that they may have actually learned the most about practical engineering.

7 Student Briefings

An important aspect of the competitive Senior Design Project is the final briefing. This provides an opportunity for each team (faculty team included!) to present their design rationale and details of implementation. Good and bad design decisions become apparent, and lively discussion often results as students compare the approach they took with a more (or less) successful approach taken by another team. This interchange is unique to competitive projects, and provides a stimulating learning opportunity. Students experience directly the diversity of approaches possible to achieve a given design objective, and have a chance to weigh and discuss the relative advantages and disadvantages. This phase of the competitive project usually makes the hard work leading up to it well worthwhile!

8 Types of Projects

Competition can be added to a wide variety of design projects. The goal of the design project should be something simple and motivational in nature. The scope should be narrow enough to allow the student to achieve a working prototype in approximately one-half of a semester. This "now it works, use the remaining time to make it better" approach pushes the students to continually refine their design. Projects should be sufficiently challenging, without obvious, off-the-shelf, or trivial solutions, so that students feel a sense of accomplishment for a job well done. In order to achieve the advantages of competition (motivation and pride), it is important to avoid goals and projects that are too difficult. Completion of the project by an instructor team before it is assigned to students is *essential* because the project must be reviewed and modified as needed.

The type of design project depends in large-part on the engineering discipline of the students. Some ideas for other design projects involving competition are: a light-seeking torpedo that can find a target in a pool of clear water; a solar-powered stove for boiling water; walking obstacle-avoiding robots that could navigate a maze; a remote-controlled plane capable of automatic stunt flight; dragster cars using small, purchased internal-combustion motors; catapults capable of delivering a small payload; and an anti-lock brake system capable of stopping a radio-controlled car. Many other projects could be adapted. Those involving movement or some other physical reaction seem to provoke the greatest interest from students.

9 Conclusion

Engineering students are typically intellectually curious and competitive by nature. Adding competition between teams to the senior engineering design project resulted in greater student motivation and an atmosphere of realism. The motivation to produce the best design, in this case the fastest line-following car, is an important element in the engineering process. Involvement in the design competition by faculty as mentors brought the idea of the “customer” to the projects. Additionally, the inclusion of an instructor designed entry provided what was regarded as the “ultimate” prize - producing a design better than the instructor’s entry. The management aspects of the project, scheduling, manpower allocation, briefings, and cost-tracking, exposed the students to the non-engineering tasks associated with any product design process. By including competition in the senior design project, we have improved the student’s technical proficiency as well as expanded their view of engineering in the “real world.”

Biographies

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