Herding cats: a case study of a capstone design course

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Abstract

The eight-semester design sequence in Engineering Science at Trinity University contains three mini-capstone design experiences (one mechanical, one chemical, and one electrical) and one capstone design project in the senior year. Senior design is so unlike the well-defined design projects encountered thus far in the curriculum, even the mini-capstone design projects encountered in the sophomore and junior years, that seniors were often spending months (and sometimes a whole semester) generating a well-defined set of specifications and criteria for their design. This paper describes our attempts to guide this discovery and analysis process without losing the essential skills learned.

We have divided the yearlong design process into six generic phases. Associated with the phases are written reports and oral presentations. The definition of and the actual content of each phase differ among the student groups, due to project choice and/or the preferences of the group advisor. By dividing the design cycle into well-defined but flexible phases, we have attempted to retain the best of the educational experience while accommodating six very different faculty members advising six very different projects, while providing some much-needed structure for the students.

Oral presentations have always been considered outstanding in this course. The structural changes have noticeably improved report writing and seem to have decreased the time spent in the initial stages of the projects. Due to this new structure, both faculty and students have the opportunity to recognize problems earlier in the design cycle, and, administering the course is a bit less like 'herding' cats!

Background

Trinity University is a primarily undergraduate institution in San Antonio of approximately 2400 students. Trinity is a well-regarded liberal arts and sciences institution, and incorporates several preprofessional programs such as Business and Engineering into the university. The Engineering Science Department is a small and intellectually diverse department, with 9 faculty members (4 mechanical engineers, 2 chemical engineers, and 3 electrical engineers) and approximately 120 students. The department features a broad-based engineering curriculum devoted to a liberal and integrative engineering education in the context of the University's tradition of the liberal arts and sciences.

The Engineering Science curriculum emphasizes an in-depth understanding of the fundamentals of the physical sciences, mathematics, and engineering sciences, which form the foundation for technical work in all fields of engineering. Some specialization is available through elective courses in chemical, electrical and mechanical engineering, taken during the junior and senior years. The program provides significant hands-on experience through engineering laboratories and participation in engineering projects required in eight semester-long design courses. The emphasis on fundamentals is intended to prepare students for dealing with the rapid pace of technology and the interdisciplinary nature of engineering practice. The laboratory and design portions of the program provide the students with a balanced perspective on the theory and practice of the engineering profession[1].

The design sequence includes a first year experience consisting of two three-hour courses, each of which has a small-group design project. These courses also provide an introduction to engineering, to CAD and to a variety of computational tools. The second year has two one-hour design courses that include small-group projects and provide introductions to engineering economics and statitistical methods. The projects (one being a mini-capstone project) in the first two years have themes that are principally mechanical in nature. In the third year there are also two one-hour courses: one deals with design from an electrical engineering perspective and the other with thermal/fluids (chemical). Each third year course has a mini-capstone project related to its respective specialty.

Introduction to Senior Design at Trinity

Since the early days of the Engineering Science Program at Trinity, a full year of senior design (two three-hour courses) has been the capstone of the program. For the past fifteen years, the two-course senior design sequence has capped eight semesters of design courses[2,3]. In the mid-eighties, the senior course sequence evolved into the form that immediately preceded the changes described in this paper. Throughout this past history of the course, the department has attempted in a variety of ways to reconcile the educational setting and goals of the course with a desire to model senior design as a professional design experience. The traditional structure of the course also represents a compromise between an industrial management scenario and the more-independent modes for faculty common to higher education. An introduction to the structure that existed prior to the recently implemented changes follows:

In the spring of the junior year, students would select potential projects that were solicited from students, faculty and industry. Five or six faculty served as group advisors for projects and three to five students would be assigned to each project. Students indicated their project preferences and the administrator made the final assignments. The assignment methodology was ad hoc and informal, but worked reasonably well. In the fall of the senior year, the groups would begin their projects. In the fall the groups would make a public presentation regarding the project after about a month, and another near the end of the semester. The public presentations were given in a medium size lecture hall, with the audience being the engineering student body (from first year to senior), the engineering faculty, and guests from industry and the university administration, totaling about 150 people. A single long, formal report was generated at the end of the semester. Each student kept a journal of their work on their project.

The spring semester proceeded in much the same way: two public presentations and a final report, with about the same timing as in the fall. During the year, the group advisors' roles were to be that of project leaders, motivators and consultants[4]. The details of group management, deadlines, meeting times and frequencies of group meetings with an advisor were entirely up to the faculty member serving as group advisor.

One faculty member (who usually was not a group advisor) served as course administrator and in some ways acted as higher management. The administrator met weekly with the entire class, and in recent years required a weekly e-mail progress report from each student. Student evaluation for each semester was provided by the whole departmental faculty: the group advisor's grade weighted at 75%, the group administrator's at 20%, and the average of the rest of the faculty at 5%. It has long been a part of the department's culture to involve each member of the department faculty in the capstone design course—as administrator, or as group advisor, or consultant, or as an evaluator. 'Herding cats' doesn't just refer to the students.

Challenges Identified with Previous Structure

In the structure just described, the group advisors operated relatively independently of the course administrator and of each other. The course administrator had managerial control over the groups to some extent, but the advisors had primary control over the projects. Each group advisor brought to a project their own professional experiences (or lack thereof) and their own pedagogical philosophies[4]. This is still the case, as senior design follows the "golden rule" --- the one who has the gold (in this case being grades) makes the rules. As a result, the student experiences vis à vis the nature and operation of the projects varied significantly among the groups. The organizational styles of the advisors varied from laissez-faire to fairly rigid.

The students had no course-wide deadlines except the presentations and papers. It's not surprising that the public presentations became the principal deadlines, since the students were loath to show lack of progress to their peers. The time spent by students on the course would skyrocket in the week or two before each presentation—not just to prepare the presentation, but also to generate sufficient progress in the project on which to present! Cleary and Jahan refer to this same challenge in revising a civil and environmental engineering capstone design course at Rowan University[6]. The presentations tended to be quite good to most of the audience, but the faculty often complained of a lack of technical depth, particularly in the areas of engineering analysis and comparison of proposed solutions. In fact, the students faced a quandary in trying to deliver technical content, yet meet the needs of a general audience.

For many groups, this structure and deadlines resulted in the following design progression:

Presentation 1 (early fall):	project description,
Presentation 2 (late fall):	rough design (proposed),
Presentation 3 (early spring):	beginnings of a physical prototype,
Presentation 4 (late spring):	pretty much complete, but "still has one or two bugs"

Latino and Hagan[5] of Oklahoma State refer to this situation in describing their 50/90 rule, "When you are sure that your project is 90% complete, then you are halfway there!" The number of completed and working projects each year was unsatisfactory to the faculty.

The reports (one per semester at the end) were often written in a hurry and sometimes not handed in early enough to permit any editing and revision. Feedback was therefore often only given once, at the end of the first semester. Group advisors had discretion to give more detailed and frequent feedback, but this was not commonly done.

Targeted Changes: A New Structure

In Fall 2000, a new structure was implemented for the senior design course. This structure contains six generic phases in the design of a product, and imposes deadlines on the design group. Each group advisor defines the specific content of the phases as well as the features of deliverables throughout the academic year. The six phases are shown in Table 1.

Table 1: The Phases of a Design

Phase	**Report**	**Presentation**
Generation of design specifications	Memo Report (~1page)	Public Presentation
Consideration of alternative solutions	Summary Report (1pg/alternative)	
Design and construction of a prototype solution	Formal Report (~10 pages)	Technical Presentation
Design and execution of a test plan for this prototype	Informal Report (~10 pages)	Technical Presentation
Modification of the prototype solution	No report submitted.	
Testing of the final solution	Formal Report (~20 pages)	Public Presentation

Written reports of various formats are required at the conclusion of each phase, and discuss only the relevant design phase. Presentations are associated with four of the six phases, as indicated above. The "Public" presentations are in the same lecture hall as before and utilize presentation software and demonstrations. A "Technical" presentation has an audience of only seniors and faculty. These presentations usually utilize overhead projector transparencies and chalkboard, and are intended to be representative of a technical project discussion among peers, and to address faculty complaints about lack of technical depth in project design.

This structure attempts to do some of the project planning and scheduling (typically a weak area for students[5,7]) and gives students some idea of what stage a design should be in at any given point in time, while allowing the group advisor enough flexibility to fit the structure to differing projects and to fit individual pedagogic preferences. Dutson et al[8] cite the trend of capstone courses becoming more structured, for many of the reasons cited above. The exact definition of deliverables (e.g. what features a "prototype" should have) and content of each phase (e.g. what is meant by "consideration of alternatives") is left to the group advisor. This layout tracks well with the 50/90 rule[5], attempting to force as much of the design into the first half of the time as possible.

Some changes have also been implemented in the selection of the projects and the allocation of students to groups. As before, proposals are brought to the juniors in the spring. Following some preliminary exposure to the proposals, the students individually discuss the proposals with faculty, industry and their peers. Near the end of the semester, juniors provide next year's course administrator with a project application in which they give three ranked choices and include a description of their first choice project (the project definitions are still somewhat fluid at this stage) and of their qualifications for contributing to that project. This is similar to the project proposal done in the capstone design course in mechanical engineering at the University of Idaho[7], and helps to acquire student "buy-in" to the projects. At the end of the semester, the course administrator and group advisors meet to evaluate the student choices and finalize project selection and staffing.

Outcomes to Date

We are now in our second year of the new structure. The "Public" presentations are still quite good as presentations to a general audience. The "Technical" presentations are better in the second iteration than in the first, but the students still don't seem to fully appreciate the desired differences between the public and the technical (and faculty still aren't satisfied with the technical content in the new "Technical" presentation format).

Written reports are better, but there have been problems with citing sources of figures, etc. The variety of report formats has been of some concern to students—sometimes groups have provided full-blown reports when something simpler was requested. However, the students have more opportunities to receive feedback from both the group advisor and the course administrator regarding the reports and to edit them before a lasting grade is assigned. This structure also encourages group advisors to give more frequent feedback to the students on their progress, but allows the group advisors academic freedom to decide exactly how this is done. There have been occasions where the report feedback process has been beneficial to the technical progress of the project.

Milestones seem to be having the desired effect—calendar-based deadlines associated with specific project goals—in most cases, but not all. Some projects don't fit the milestone-scheduling scheme as well as others (or the group advisors have not bought into the schemes --- remember the golden rule, the group advisor still has 75% of the gold), despite our first attempts to make the nature of the milestones flexible. Also, we have noticed the phenomenon commented on by Cleary and Jahan of Rowan University[6], that in the face of a seemingly overwhelming project, groups often work in deadline-oriented crisis mode instead of engaging in long-term project planning. Thus, at a level we concur with their prediction that more frequent review may simply lead to the students working in crisis mode more often! On average, however, we believe that the additional structure has improved the chances for success for the projects.

Conclusions

We believe that the structural changes have provided a better scheme for guiding and evaluating the students in their execution of senior design. We also believe that we've done this without unduly removing the freedom of group advisors to structure their individual projects as they see fit. Nonetheless, problems still exist with communicating with the students regarding the exact nature of the milestones, the faculty's desires in some aspects of reports and presentations, and the successful execution of the projects. Finally, the traditions of departmental total involvement—so deep in our culture—still has us herding (faculty) cats!

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