Leveling the Field

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The Tufts University Civil & Environmental Engineering capstone course experience has undergone revision to address some uneven results. Three areas of concern were addressed. First, different grading schemes used by different faculty directing projects was eliminated by using two faculty to manage all student groups, with help from other faculty and outside practitioners. Second, variations in group size and corresponding student work load were remedied by selection of student groups that were the same size and of similar composition. Finally, differences in design complexity due to differences in the type and scale of group projects were leveled by having all student groups work on a variation of the same design project. Approaches not changed included maintaining uniform time demands throughout the semester and use of a real site. Uniform time demands has shown to reduce last-minute scrambling. Use of a real site continues to allow involvement of practitioners on the project and its scoring. All faculty members were involved in scoring all groups' reports, generating an atmosphere of equity for students and faculty. Also during the course revamping process, a module concerning professional and ethical practice was introduced to ensure required student outcomes were thoroughly addressed.

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Overview

The capstone course in the Civil & Environmental Engineering Department at Tufts University is a one-semester group design project taken in the second semester senior year[1]. These group projects have sometimes varied in quality. Variations in technical report length and complexity have resulted from different faculty managing student teams that ranged in size from two to eight members. Expectations of design project complexity vary from one faculty to the next, leading to uneven student expectations. "Cherry picking" by faculty prior to formal student team selection also led to uneven group composition. Students have shown discomfort in being saddled with a realistically difficult project from a stern faculty leader, especially when their peers appear to have easier paths to the same grade only due to being in a different project group with a different faculty leader.

At the same time, the capstone course experience is a key opportunity for students to meet their requirements for meeting ABET accreditation outcomes criteria such as the ability to function on multidisciplinary teams and the understanding of professional and ethical responsibility. In order to demonstrate that these outcomes are being met, appropriate rubrics needed to be implemented in this course.

In order to meet these goals, a restructuring of the capstone experience was tested. Student groups of the same size were selected by a faculty team based on student grade point averages (GPA) and students' self-identification of fields of expertise within Civil & Environmental Engineering. GPA values were used to ensure that there was a mixture of student class standings within each group, so that there were no "all-star" or "all-dud" groups. Student expertise was distributed across each group so that coverage of at least three areas selected from environmental, geotechnical, structural, or water resources engineering could be used by every group. All student groups were to work on a self-selected variation of the same design project. Three formal reports and presentations were required during the semester. All departmental faculty were encouraged to attend the presentations and score all of the groups. Half of the course meeting times was devoted to speakers addressing the specific project site as well as general presentations concerning engineering practice. A course module involving ethics used one fifth of the course meetings and was coordinated with a member of the Philosophy department.

Student Groups

Group size in capstone projects in our department have ranged from two to eight students[1]. In order to optimize tradeoffs between group size and productivity, a group size of about four students is our target, also limited by the total number of students in the class. For example, with a total class size of fifteen students, three groups of five students each were used. Others have found best group sizes of four to five students, with problems associated with larger groups[2,3,4].

Composition of student groups is equally mixed as to expertise. Students self-selected their areas of expertise

from structural, geotechnical, environmental, or water resources engineering. By such mixing, interdependence is promoted, with each member expected to contribute to the project according to their area of interest. Such balanced mixing of group composition leads to increased group stability and student perceptions of fairness[5,6,7].

Project Selection

Group project sites in our department have ranged from national competitions to international aid[8,9]. Such a range of projects has led to differences in expectations from students and project sponsors. There have been resulting differences in the quality of project report produced by different groups in the same class year, leading to student perceptions of unequal workloads and unequal grade scales. Past practice was to have individual faculty advise self-selected groups, that led to uneven faculty workloads taken in addition to their normal teaching duties. At times there would be some faculty heavily involved in capstone projects, with others only peripherally involved, and some not at all. In order to eliminate these differences, student groups were assigned to the same project site, with variations on their design projects at their discretion. A team of two faculty members was selected to manage the course, with evaluations of project presentations required from every other faculty member. Consistency in expectations led to consistency in student workload and an overall high level of project quality. To maintain a high expectation of product, a real project at a real site was selected. This allowed interactions with practicing professionals so that classroom ideas could be translated into practical results. The feedback from project sponsors in addition to faculty expanded constructive criticism of student work, as seen by others[3,10]. Having all students work on variations of the same project also eliminated "cherry picking" by faculty or students, enforcing one factor in leveling student group composition. Using a common project site also allowed a selection of practitioners involved with the site to address the entire class at the start of the semester. This common starting point benefitted all students.

Protocols Maintained

The entire capstone experience in our department was not discarded and replaced. The use of a one semester course was kept, as has been shown useful by others[2]. Our positive experience with effort leveling[1] was also kept. The idea of effort leveling is to maintain a constant effort load, and to avoid the phenomenon of only working at the time of project deadline[11]. To meet this goal, deliverables are spread throughout the semester in the form of three formal reports and presentations by each student group. The presentations are attended by all groups and scored by all faculty, leading to competitive spirit between groups. Each student is also required to submit critical summaries of the other groups' presentations. The first presentation and report outlines the expected scope of work. The second represents a fifty percent progress report with projections of work to be completed. At the second report stage, there is still time for minor modification of the project scope as well as an acknowledgement of branch points evaluated and paths of effort taken. The final written report and formal oral presentation is at the end of the semester. By spreading the deadlines throughout the semester, student effort is leveled as idealized in Figure 1.

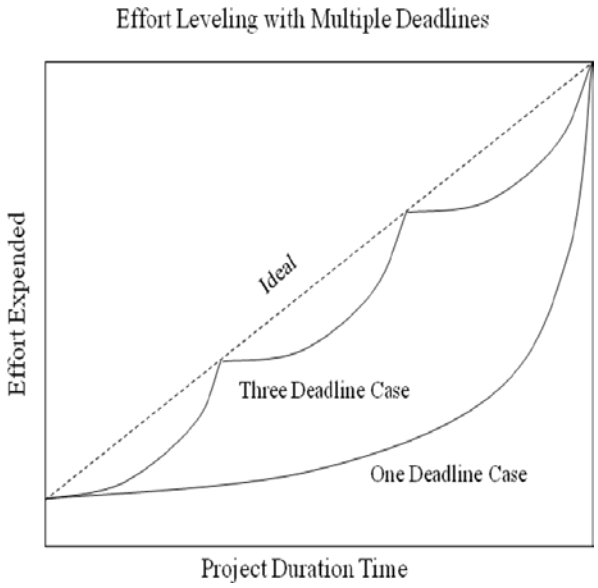

Figure 1. Idealized Effort Expended versus Time

Assessment of Outcomes

The ABET-based outcomes addressed by the capstone course in our department include the following:

- Ability to apply knowledge of mathematics, science, and engineering.
- Ability to design a system, component, or process to meet desired needs.
- Ability to function on multi-disciplinary teams.
- Ability to identify, formulate, and solve engineering problems.
- Understanding of professional and ethical responsibility.
- Ability to communicate effectively.
- Recognition of the need for and an ability to engage in lifelong learning.

- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
- Preparation for professional leadership.

These outcomes are often covered in multiple courses, and there are rubrics useful for their evaluation. Those outcomes whose coverage is central to this course include the ability to function on multi-disciplinary teams; understanding of professional and ethical responsibility; and preparation for professional leadership. The evaluation criteria in the rubrics serve a dual role, both establishing expected goals and measuring student performance. Expectations that are formally structured, and accompanying feedback to student groups, is important in maintaining consistently high quality student projects[6,11,12]. Engaging the faculty, students, and sponsors in assessment is also central to making student groups feel they are contributing useful effort and being properly recognized for their work[3].

An example of an outcome central to this course is the understanding of professional and ethical responsibility. In order to address this outcome, seven of the thirty-two class meetings are devoted to a course module developed to explore professional and ethical issues. This module was developed with the help of a practicing engineer as well as a member of the Philosophy department who teaches an ethics course. The components of the ethics rubric include the following;

- Awareness of the ASCE Code of Ethics
- Ability to recognize potential ethical problem situations
- Awareness of the responsibility to work in a professional and ethical manner

Professional and ethical issues are addressed in many courses in the undergraduate curriculum. Students also are instructed in ethical behaviors in mandatory campus discussion groups at the time of first-year matriculation. Those workshops, however, are perceived by students to be focused primarily on academic and social issues such as plagiarism and abuse. By using this module concerning professional and ethical issues, students' ideas concerning the breadth of ethical issues are expanded. Making students aware of professional and ethical issues prepares them for professional practice.

Conclusions

The ongoing evolution of the capstone experience in our department at Tufts University is meeting students' needs and program objectives. By leveling the field with regard to student group composition, uneven talents in a class can be spread so that no group has unfair advantages or disadvantages. By using variations on a theme within the same design project for all groups, performance expectations are equalized. Differences in faculty participation and expectations are leveled by the actions of the two faculty members managing all student groups with the help of outside practitioners and other interested faculty. Involving all faculty in evaluating all groups' reports, as well as the same cadre of practitioners with all groups, makes it clear to the evaluators what differences exist between different groups that are producing similar but not identical designs. Having the same scoring rubrics apply to similar projects presents a clear outcomes scale to accreditation professionals. Those same shared rubrics also allow students to feel evenly evaluated and fairly graded for their efforts. Student feedback from group meetings, course evaluations, and exit surveys indicates their perception of even-handed evaluation of their work, in contrast to past reports of disappointment over the wide range of efforts required to satisfy different faculty leading different projects. By maintaining consistently high standards across all groups, project quality is maintained at a high level. Students respond well to consistently high expectations, leading to their creation of a product in which they take pride.

Including a module concerning professional and ethical issues provides a clearly identifiable process for reaching a required outcome. This approach should aid in program evaluation at the time of accreditation.

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