Senior Engineering Design: Grading by Objectives

by

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Abstract

This paper describes the performance-contract evaluation system, Grading by Objectives (GBO), used to grade UTC's Senior Engineering Design Project (Project). This Project employs all of the College's engineering seniors as the project management and design team, in a two-semester interdisciplinary design effort. During the past few academic years, the instructional approach to the Project has been modified to emphasize strategic planning, management, individual accountability and communication. This was accomplished by moving the instructor-student interaction away from classroom instruction to a corporate boardroom and electronic reporting format [2], an renewed emphasis on the steps of the design process[3], and requiring individual performance to determine grading.

Introduction

During the three decades of instruction of the senior design project, the grading system has been varied from giving the whole class the project grade determined solely by the project reports, to a very detailed point earning system where every action was assigned a weight and point scale in the final grade. In every case the grading system has had at least two significant problems: determining what has been each individual's contribution to the project, and motivating students to suggest and complete suggestions to enhance the project. Recognizing this need, the authors proposed a performance-based plan which fits the move away from classroom instruction to a quasi-industrial setting. The grading by objectives contract is based on the well known management-by-objectives plan, and on accepted industrial principles of hiring and performance bonus incentives.

This paper describes the Grading by Objectives Contract as applied to the Senior Engineering Design Project. Students were provided with grading contracts, which specifically related the grades earned to the performance, reporting and communication processes. With this contract, students have greater awareness of the performance evaluation process and enhanced communications, despite reduced classroom interaction. The early results indicate increased self-involvement by the students, leading to greater responsibility and autonomy in the grading system.

The College of Engineering and Computer Science at the University of Tennessee at Chattanooga (UTC) is among a few ABET accredited engineering programs that incorporate a class-wide Senior Engineering Design Project during the two semesters of the students' senior year. The Project is consistent with the interdisciplinary form of the engineering program at UTC, which offers a BS degree in Engineering (not in any one discipline) with a concentration in one or more of the traditional disciplines of engineering.

The Project is interdisciplinary. Students are required to work together, as an organized Project Team, to complete a meaningful design, from defining customer requirements through all design phases in the first semester, and construction, testing and delivery of the end product, when feasible, in the second semester.

The interdisciplinary engineering curriculum at UTC enables students to work effectively in functional, rather than discipline-based, Project sub-groups, due to their broader academic backgrounds. This has been an inherent strength of the Project, which has, in turn, reinforced the inter-disciplinary academic training. However, the Project was designed to accomplish more.

The Senior Engineering Design Experience

The UTC College of Engineering and Computer Science has used the Senior Engineering Design Project as a vehicle for providing students with several experiences that they would gain during their employment as engineers and engineering managers.

The Project is expected to provide, in addition to engineering design, experience in: organization, human factors, project management, quality, safety, environmental factors, economic analysis, budgeting, procurement, documentation, reporting and ethics. This neither is an exhaustive list of the desired course objectives, nor is it a list of accomplishments that any one graduating class or instructor can claim to have achieved with this Project. Rather, it is a partial list of desirable achievements

that the Project can set out to accomplish.

The Li'l REV Design Project

The Design Project is an on-going program for electrical vehicle design, development and performance measurement, with the long-term objective of competing in the Electric Vehicle Technical Competition (EVTC) program[3].

In the Fall of 1996, the faculty developed their vision of a "Hybrid Re-Chargeable Electric Vehicle (EV)" that would be the pit or utility vehicle used to tow a competition vehicle at race facility and carry crew and pit apparatus to and from the paddock and pits at the EVTC competitions. The students were briefed on the EVTC organization and informed that several major State and private universities across the country had EV programs and that EVTC competitions were held several times annually to select the best performing EV design.

The First EV Design course then was tasked to design, build and test a rechargeable electric powered support vehicle. The project was named "Little Rechargeable Vehicle, or Li'l REV." This process of selecting the name for the Project helped in getting the students immediately involved in the Project.

The first year of this Design project, the Li'l REV vehicle was designed and the basic pit vehicle was constructed. During the 1997-98 year, ancillary and hybrid systems for the vehicle were designed and partially constructed. During this 1997-98 year, structural analysis and electronic control systems are being designed. The framework for planning, execution and evaluation is being implemented through Twelve Steps of Purposeful Action [1].

Reporting and Communication

In keeping with the industry or corporate model adapted for the Li'l REV project, all management and operational responsibilities are delegated to the student-staffed Project Management Team. The following communication and reporting requirements are established in collaboration with Project Management Team, starting with the second week.

Weekly Reports, in a specified format, submitted by each student to the next higher level of management, graded by each level of management and submitted to the instructors through the Project Managers. Students are asked to report on all work performed, time worked and group meetings and telephone conversations held during and outside of class hours.

Minutes are kept of all Board Meetings, which are held weekly, outside of class hours. One Group Manager is scheduled to present a Group Status Report to the Board each week. Special reports are scheduled for presentation, as appropriate. Agenda are required for all Board meetings.

Minutes are kept of all class meetings, which were held twice weekly. These meetings are managed entirely by the Project Manager, with the instructors acting as observers and consultants. Agendas are required for all class meetings.

Milestone reports are prepared by the entire Project team.

Milestone presentations are made by selected members of the Project team for each Project milestone, accompanied by copies of the slides prepared for the presentation.

Individual technical presentations are required by each student, at least once each semester, accompanied by copies of the slides prepared for the presentation.

Project Grading Contracts

Students expressed frustration with trying to assign grade points to each action, and forcing an unrealistic grading system onto their efforts. Along with their autonomy in the design process, they wanted to know that their performance affected their grades, much like performance would affect their salaries and promotions later on the jobsite.

In response to this need, the GBO reward structure was implemented. The student handout explaining the Grading by Objectives (GBO) reward structure is given at the end of this paper as Figure 1.

Grading by objectives is a performance oriented system based on identifying goals, objectives and desired results, establishing a program for obtaining these results, and evaluating and rewarding performance in achieving results. An effective system is one in which objectives are clear, and there are no surprises when the evaluation occurs. Evaluation of engineers' performance is one of the most significant responsibilities of group managers, project managers and peer engineers.

PERFORMANCE RATINGS

The evaluation of the performance of engineers, group managers, and project managers focuses on three areas: contribution to forming group objectives and task assignments, performance towards achieving group objectives and tasks, and significant bonus contributions to the project, the senior design course, and/or to the College of Engineering.

GROUP OBJECTIVES AND TASK ASSIGNMENTS

Course and group objectives are not assigned on a top-down basis by faculty, rather the groups are expected to proceed from a stated vision, mission statement and milestone deadlines to the development of appropriate objectives and assignments. After the discussion of the project vision, development of a project mission, presentation of customer expectations, development of draft specifications and scheduling of milestone dates, group managers, in conjunction with their group engineers, develop group objectives, group task requirements, group deliverables and appropriate deadlines toward the milestones and deliverables. These tasks and deliverables are then assigned, by mutual agreement, among the group engineers. At this point, it should be clear to all parties what performance is expected.

PERFORMANCE TOWARDS GROUP OBJECTIVES

Performance towards group objectives is evaluated by accomplishments on weekly reports, deadlines met on time, quality of deliverables, milestone reports, and manager and faculty qualitative evaluations.

SIGNIFICANT BONUS CONTRIBUTIONS

Raising of the grade compensation more than one grade level above the hiring level requires initiative or achievement beyond that normally expected in this course. Engineers or managers who wish to receive an evaluation of Exceptional Merit Performance and a bonus grade level are required to suggest tasks, reports, presentations or other achievements beyond normal expectations, in order to be considered for a bonus in grades. The suggestion is approved by the appropriate managers, and forwarded to the Board of Directors for approval.

An evaluation of each area and a composite evaluation of all three areas are performed by the group managers for each engineer in their group, by project managers for each group manager, by engineers for their managers, and by group managers for the project manager. Each performance area is assigned performance ratings according the following designations:

Exceptional Merit Performance: bonus raise in compensation recommended

Above Merit Performance: raise in compensation highly recommended

Merit Performance: raise in compensation recommended

Below Merit Performance: recommend no raise or loss of compensation.

Performance Evaluations are forwarded to the Faculty for final award of grades. There is a direct correspondence between the GBO evaluation and the grades awarded in compensation

GRADING SCHEME

Grade compensation for the senior design course is as follows:

Engineers

Engineers to work in groups are hired with a grade of C. At mid-term, there is a performance evaluation by the Group Managers, the Project Manager and the Faculty. A grade recommendation is made, and assigned to the engineer as a mid term grade.

At course's end another performance evaluation results in the final grades.

Managers
Group Managers, and the Project Manager are hired with a grade of B. At mid-term, there is a performance evaluation by the Managers, the Engineers and the Faculty. A grade recommendation is made, and assigned to the Manager as a mid-term grade.

At course's end another performance evaluation results in the final grade**.**

GRADING CRITERIA
The satisfactory completion of all project tasks, other assigned course tasks and reports, on time, results in an evaluation of Merit Performance and raise of one grade level total at mid-term and/or one grade level total for the final grade.

Raising of the course grade more than one grade level requires initiative or achievement beyond that normally expected in this course. Engineers or managers who wish to receive an evaluation of Exceptional Merit Performance and a bonus grade level are required to suggest tasks, reports, presentations, or other achievements beyond normal expectations in order to be considered for a bonus in grades. The suggestion is approved by the appropriate managers, and forwarded to the Board of Directors for approval.

EVALUATION RESPONSIBILITY
Thus, Engineers evaluate their managers, with review and approval by the Project Manager, the Faculty and the Board of Directors.

Group Managers evaluate their Engineers, and the Project Manager, with review and approval by the Faculty and the Board of Directors.

Project Managers evaluate the Group Managers, with review and approval by the Faculty, and the Board of Directors.

EVALUATION MEETINGS
The normal practice in evaluation would be for each employee to have a face-to-face meeting with their evaluator to discuss the evaluation so that there are no surprises.
It is recommended that this be done if practical: evaluees may see their evaluations by arrangement with the faculty.

UNSATISFACTORY PERFORMANCE
As always, unsatisfactory performance, if not corrected by guidance, will lead to a lowering of the compensation. Letters of guidance are provided in these cases, and a file built on each employee. Reprimands are given for class absences, tardy reports and for non-professional behavior, and factored into performance evaluations.

Initial Findings

Shifting the instructional emphasis from classroom lectures and guidance to self -motivated action following the Twelve Steps, and Grading by Objectives, appears to have resulted in some notable improvements in the Design Project. Our preliminary observations are:

1. **Student participation, involvement and accountability increased**. This was evidenced by a 100% attendance record (including pre-excused absences), submission of weekly reports on time and student proposals for bonus compensations above and beyond normal expectations.

2. **Faculty involvement increased, but with quality time, not just busywork**. This is due to the reviewing and grading of weekly and special reports and attending weekly Board meetings.

3. **Students' satisfaction with the course increased.** This is because the students have a direct input into their grades, and are accountable to fellow students in the evaluation process

The development of design skills has been a cornerstone of the Senior Engineering Design Experience at the University of Tennessee at Chattanooga. The Li'l REV Construction Project takes this process a step further by ensuring that each student experienced the design steps in a structured and performance-based setting.

References

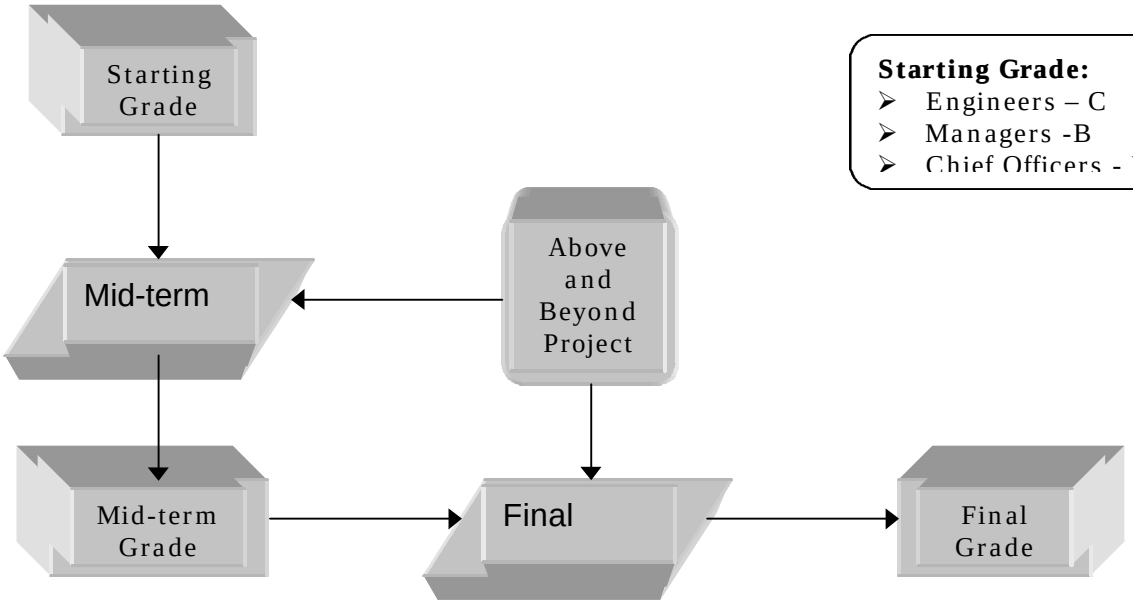
1. P. S. Chopra, " The Twelve Steps of Purposeful Action," Engineering Management Textbook, Manuscript in preparation. 1997

2. P. S. Chopra, V. A. Thomason, and Robert Wynn, " Senior Engineering Design Project: From the Classroom to the Boardroom," Proceedings 1997 ASEE Southeastern Section Meeting, pp. 28-33, Marietta, Georgia, 1997

3. V. A. Thomason, P. S. Chopra, "Twelve Steps of Purposeful Action for Senior Engineering Design," Proceedings of the 1998 ASEE Southeastern Section Conference, Orlando, Florida, April 1998.

4. Electric Vehicle Technical Competitions, L.C., P.O. Box 11088, Glendale, Arizona, 85318, Ph.602/978-1373.

Figure 1. Grade Determination Flow Chart



Starting Grade:
- Engineers – C
- Managers -B
- Chief Officers - B

Note:
- Only letter grades are given in the course. Grades may increase or decrease based on performance evaluations twice per semester.
- Engineers evaluate their managers with review and approval by the Faculty.
- Project Managers evaluate their Engineers and the Chief Officers with review and approval by the Faculty.
- Chief Officers evaluate the Project Managers with review and approval by the Faculty.

Above and Beyond Project: Raising the course grade more than one letter grade requires initiative and achievement beyond what is normally expected. The Board of Directors must approve all Above and Beyond projects before they can be done. The Board will review and evaluate the project at its' completion (at mid-term or final time). At this time a grade increase may be given based on an evaluation of the project.

Mid-term and Final Evaluation: The grading criteria, at these times, is based on satisfactory completion of project tasks, completion of weekly reports, attendance, oral presentations, Above and Beyond Projects, and an over-all evaluation of performance. At mid-term only, all class members are eligible for a raise of one letter grade. At the final evaluation, all student files will be evaluated but grade increases will only be given for Above and Beyond projects.

Final Grade:
- An Engineer's grade may raise one letter grade during the semester unless an Above and Beyond Project is completed and evaluated. Therefore, the resulting grade can stay the same, be raised one to two letter grades, or drop based on performance evaluations.
- The Manager's and Chief Officer's grade may raise one letter grade during the semester. Therefore, the resulting grade can stay the same, be raised one letter grade, or drop based on performance evaluations.

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Virgil Thomason served as a Field Engineer, and then Training Director for The Western Union Telegraph Company from 1960 to 1971, installing, testing and then training on data communication systems for the Department of Defense, and for private industry.
He joined the University of Tennessee at Chattanooga (UTC) 1974, teaching any of the undergraduate EE courses, and graduate courses in digital signal processing, stochastic processes and computer interfacing.

PREM CHOPRA

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