

Twelve Steps of Purposeful Action for Senior Engineering Design

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Abstract

This paper describes the Twelve Steps of Purposeful Action [1] and the performance-contract grading systems which are used to implement UTC's Senior Engineering Design Project (Project). This Project employs all engineering seniors as the project management and design team, in a two semester interdisciplinary design effort. During the past academic year, the instructional approach to the Project was modified to emphasis strategic planning, management, individual accountability and communication. This was accomplished by: moving the instructor-student interaction to a corporate boardroom and electronic reporting format, away from classroom instruction [2], and requiring individual performance to determine grading.

During the second semester of the newly structured Design Project, it was discovered that the students required considerable guidance in restructuring their thinking from instructional guidance to self-motivation. Recognizing a need, the authors provided a framework, Twelve Steps for Purposeful Action, which the students referred to and utilized in their planning, execution and reporting activities. Based upon the experience gained from the Design Project, and from instruction to undergraduate and graduate students in industrial engineering and management over the several years, this framework has evolved into the Twelve Steps. These Twelve Steps incorporate the generally accepted processes for management and engineering design, but include additional elements which the authors have found to be key to the success of the Design Project.

This paper describes the Twelve Steps of Purposeful Action as applied to the Senior Engineering design Project. With these Steps, students have greater awareness of the performance and progress of work, and enhanced communications, despite reduced classroom interaction. The early results indicated increased self-involvement by the students, leading to a desire to have greater responsibility and autonomy in the grading system. Consistent with the new framework, students were provided with grading contracts, which specifically related the grades earned to the performance, reporting and communication processes of the Twelve Steps.

Introduction

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 selected for this experimental redesign study was 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).

At the start of the first class session, the instructors described their vision of a "Hybrid Re-Chargeable Electric Vehicle (EV)" that would be the pit or utility vehicle used to tow a competition vehicle 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.

In the Fall of 1996, the students were informed that their two-semester design experience was the first of a series of on-going design courses on EV design, construction and performance testing for future classes of seniors. Consequently, they would have a disproportionately higher burden for planning. They would have to plan their Project activities during their two-semester course, and set the course for a long-term Hybrid High Performance EV Project for future classes of seniors.

The First EV Design course then was tasked to design, build and test a rechargeable electric powered support vehicle. The students then were asked to suggest names for the Project. Based upon a vote in which all students participated, 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.

During the first year of this on-going Design project, the Li'l REV vehicle was designed and the basic pit vehicle was constructed. During the 1997-98 year, the hybrid systems for the vehicle are being designed and will be constructed. 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 were delegated to the student-staffed Project Management Team. This made it mandatory for the Project Team to conform with a structured and detailed system for reporting and communicating. Consequently, the following communication and reporting requirements were 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 Manager. Students were asked to report on all work performed, time worked and group meetings and telephone conversations held during and outside of class hours.

Special Reports, as assigned. Examples of special reports that were completed are: the use of intranets as a design communication tool; design and implementation of a database management system for the Li'l REV Project; operating procedures and management guidelines for the Li'l REV Project; and the long-term plan for the electric vehicle design program.

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

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

Milestone reports were prepared by the entire Project team.

Milestone presentations were 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 were required by each student, at least once each semester, accompanied by copies of the slides prepared for the presentation.

In addition to these structured forms of oral and written communication, the students were encouraged to seek the guidance and assistance of the instructors, other members of the engineering and computer science faculty and external experts. Students were instructed to document each of these interactions and provide copies, in electronic form, to the Assistant project Manager for Reporting. This information was then incorporated into the Project's electronic database. In turn, each student was provided access to all the reports and information generated by individual students and by the Project Team, and incorporated in the database.

The instructors' evaluations of reports and performance of individual students, however, were not included in the database. The Project database is expected to be particularly useful to the on-going EV Program by capturing Project memory and experiences, and making them readily available for use by subsequent Senior Engineering Design classes.

Twelve Steps of Purposeful Action for Engineering Design

During the construction phase of the first year of the project, students had considerable trouble adapting to the self-motivated mode required because of student autonomy provided by the boardroom approach. While it is not thought to be possible to create a recipe for the design process, it is possible to provide a framework for students to follow, so that they know where they are in the process, and what they should be doing. This framework has evolved into the steps described below.

Purposeful action involves twelve steps. These twelve steps, which surround purposeful action are grouped into three phases, in addition to the action phase. These are outlined below:

- Phase I: Establish the purpose for the Design Project by reaching inside yourself. The key is the Mission of the Project.
- Step 1: Introspection
 - Step 2: Realization of Vision
 - Step 3: Formation of Mission: Commitment is made to the Mission

Phase II: Develop the Plan to accomplish the Mission. This follows the established steps of project management, which are represented here by Steps 4 through 9.

- Step 4: Setting Goals, Group and Individual
- Step 5: Defining the Strategy: The most effective Path to the Goal
- Step 6: Planning: The map for implementing the Strategy, incorporating Tasks, Schedules, Costs and Controls
- Step 7: Organizing: Allocating resources to the Plan
- Step 8: Building the Team: Staffing and Affirming responsibility and reward relationships
- Step 9: Guidance: Teamwork: each member doing contracted tasks while assisting others in activities aligned with the Mission

Phase III: Purposeful Action. Where each member of the team is released to do assigned actions to accomplish the Mission.

Phase IV: Evaluation and Renewal.

- Step 10: Assessment: Where the results of the action are evaluated and compared with the Plan and with changes in internal and external environment.
- Step 11: Renewal: Involves revising the Plan based upon the assessment, including reassignment of personnel and resources.
- Step 12: Reinforcement: Affirming the Mission and the revised goals, plan, organization and staffing, consistent with prior and renewed staff (grading) contracts.

Application of the Twelve Steps

Students had considerable trouble adapting to student autonomy during the construction phase of the first year of the project. While it is not possible to create a recipe for the design process, it is possible to provide a framework for students to follow, so that they know where they are in the process, and what they should be doing. This framework has evolved into the Twelve Steps, which the instructors provided to the class during this construction phase.

From this point, the first response to any communication with students was, "Where are you in the Twelve Steps?" Very quickly the students learned to identify their actions with the framework provided, and knew just where they were in the design process.

Project Grading Contracts

During the application of the Twelve Steps, students expressed frustration with trying to assign grade points to each action, and forcing a 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.

Engineers were hired at a satisfactory or "C" level, and would be evaluated during the term for satisfactory performance of all tasks. After the probationary period of half the term, the engineer could be elevated to a "B" level of compensation for satisfactory performance. No further increase was available unless the engineer developed an additional innovative task leading toward a goal in support of the mission, proposed it to the manager, and received approval of the task by the Project Management Team.

Managers were hired at the "B" level, but could be raised to the "A" after the probationary period, for satisfactory performance.

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

Performance evaluations, as described in the student handout, were done at mid-term as the end of the probationary period, and at terms-end as the final grading procedure.

The grading by objectives forms as distributed and used by the class are attached as Figure 2.

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 apparent honest evaluation of student performances.
2. **Instructors spent more time on a weekly basis.** This was due to the reviewing and grading of weekly and special reports and attending weekly Board meetings.
3. **Students' efforts were more evenly distributed.** This was because the students were forced to think of the design process in each of their actions, and were 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 took 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. Electric Vehicle Technical Competitions, L.C., P.O. Box 11088, Glendale, Arizona, 85318, Ph.602/978-1373.

Evaluation and Grading by Objectives

Grading by objectives (GBO) 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.

Forming 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 is 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

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 a 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: evaluatees may see their evaluations by arrangement with the faculty.

Figure 1: Grading by Objectives Student Handout

GBO Forms

The same evaluation form is used at mid-term and at the end of the semester. A list of qualities is provided, to guide the evaluator to the final recommendation.

P	F	A	G	E	Person being Evaluated
o	a	v	o	x	
r	r	e	d	e	
					NAME _____
					DATE _____
					BY WHOM _____
Forming Group Objectives and Task Assignments					
					This person did a fair share of the work.
					This person cooperated with the team members
					This person is competent in analysis/design tasks
					This person completed assignments on schedule
					This person produced quality work
					This person attended meetings
					This person was well prepared for meetings
					I would like to work with this person on future projects
					Rating : _____ Above Merit _____ Merit _____ Below Merit
Performance on Task Assignments					
					This person did a fair share of the work.
					This person cooperated with the team members
					This person is competent in analysis/design tasks
					This person completed assignments on schedule
					This person produced quality work
					This person attended meetings
					This person was well prepared for meetings
					I would like to work with this person on future projects
					Rating : _____ Above Merit _____ Merit _____ Below Merit
Significant Bonus Contributions					
					This person suggested and performed a bonus suggestion approved by the managers and the Board of Directors
					Exceptional Merit Performance
Overall Rating:					
_____ Above Merit Performance					
_____ Merit Performance					
_____ Below Merit Performance					

Figure 2: Grading by Objectives Evaluation Form

GBO Forms

The same evaluation form is used at mid-term and at the end of the semester. A list of qualities is provided, to guide the evaluator to the final recommendation.

P o r	F a r	A v e	G o d	E x e l e n t	Person being Evaluated
					NAME _____
					DATE _____
					BY WHOM _____
Forming Group Objectives and Task Assignments					
					This person did a fair share of the work.
					This person cooperated with the team members
					This person is competent in analysis/design tasks
					This person completed assignments on schedule
					This person produced quality work
					This person attended meetings
					This person was well prepared for meetings
					I would like to work with this person on future projects
					Rating : _____ Above Merit _____ Merit _____ Below Merit
Performance on Task Assignments					
					This person did a fair share of the work.
					This person cooperated with the team members
					This person is competent in analysis/design tasks
					This person completed assignments on schedule
					This person produced quality work
					This person attended meetings
					This person was well prepared for meetings
					I would like to work with this person on future projects
					Rating : _____ Above Merit _____ Merit _____ Below Merit
Significant Bonus Contributions					
					This person suggested and performed a bonus suggestion approved by the managers and the Board of Directors
					_____ Exceptional Merit Performance
Overall Rating:					
					_____ Above Merit Performance
					_____ Merit Performance
					_____ Below Merit Performance

Figure 2: Grading by Objectives Evaluation Form

VIRGIL THOMASON, PREM CHOPRA

Virgil Thomason graduated from Case Institute of Technology in 1960. He earned an MS in Electrical Engineering from the University of Tennessee at Knoxville, Tennessee (UTK) in 1971, and a PhD in Electrical Engineering from UTK in 1977. He 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) as an Assistant Professor in 1974, and has progressed to Professor of Engineering, teaching any of the undergraduate EE courses, and graduate courses in digital signal processing, stochastic processes and computer interfacing .

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