CHALLENGES IN GRADING PROJECT TEAMS

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ABSTRACT

Project courses involving teams of students present a serious challenge to fair grading of individual students. There is the possibility that some students put in an enormous amount of work and others try to get a good grade with little effort. As the advising faculty member is not with the team at all times, there may be many activities by the team that go unnoticed. The adviser has the continuous challenge to find out which students perform and which students do not perform. The advisers must have a selection of instruments at hand that allow for best possible fair grading of team members.

KEYWORDS

Grading, team work, team dynamics, fairness

INTRODUCTION

As a National Policy the National Academy of Engineering [1] and all major Agencies have endorsed the support of the educational challenges for the STEM (Science, Technology, Engineering, and Mathematics) education. Project-Based Learning has been shown to increase the acquisition of deeper knowledge and develop in students the desired product and team skills [2, 3].

While students have had some experience working on prescribed design studies in previous courses, Senior Projects provides the opportunity for students to focus on a complex engineering problem of their choice from conception to validation. Through this process students will learn and have the opportunity to apply fundamental concepts of engineering design, manufacturing and testing in a team environment. The overarching skill learned is *Systems Engineering*.

The fundamental course objective of the CU-AES Senior Projects sequence (ASEN 4018/4028) is to teach students how to *engineer a complex, multidisciplinary design and implementation problem in a group environment* which satisfies all ABET [4] accreditation requirements. This will be achieved through a hands-on experiential learning process where students are expected to conceive, design, implement, test, operate, and verify an aerospace related system. All projects are driven by customer requirements. Typically there are 8-10 teams with 7-10 students per team.

The senior design course sequence ASEN 4018 and 4028 is a complex organization with many challenges in evaluating individual student performances. The courses are supervised by the

Course Coordinator (CC) who carries the managerial responsibilities. The CC leads the Project Advisory Board (PAB) which is composed of faculty, instructors and technical staff. Each team has one Faculty Adviser (FA) who meets with the assigned team at least once a week.
The PAB conducts formal reviews of project accomplishments at specific times during the semester, and these results are the primary source of data for compiling the team grade. Individual grades will be computed using faculty and external mentor evaluations, peer and self-evaluations and any individual assignments. The evaluation process is based around specific learning goals. Not all learning goals will be assessed at each milestone and students will receive specific details on the evaluation processes in the specific assignment document. The final course grade will be based equally on group and individual performance. Fair grading poses great challenges.

TEAM GRADES

Team grades are assigned in the following way.
The FA is primarily responsible for all report grades of her/his assigned team:

a) Project Definition Document (PDD) and Conceptual Design Document (CDD)

b) Fall and Spring Final Reports (FFR, PFR)

c) AIAA paper

a) Lab Notebook (LN) evaluation

b) Student Performance Evaluation (SPE)

The entire PAB, including technical members, has equal weight grade input for the following oral presentations:

a) Preliminary Design (PDR) & Critical Design review (CDR)

b) Interim Reviews (IR1&2)

c) Symposium and Poster presentation

INDIVIDUAL GRADES

Individual grades are based on the following elements:

The Lab Notebooks (LN) is a major vehicle for the individual student to document his/her contributions to the project. This grade is at the discretion and according to personal standards of the team's FA. In some cases the FA shares individual pages from LNs with the PAB if a student's performance is questioned.

A second metric for individual grades is the Student Performance Evaluation (SPE). This evaluation is primarily done by the FA based on the working relationship during the entire semester. No specific grading rubric exists for this effort. Elements that the FA considers are, in no particular order: weekly time sheets, meeting performance expectations, self evaluations, professionalism, ethics, participation, efforts, assigned tasks, blogging, web development, and any other component deemed important by the FA.

A third metric are the Peer Evaluations. Peer evaluations are taken into account for the PDR, CDR, IR2, and SFR. Presentation grades by students are consulted in the decision making

process. These peer evaluations have a minor effect on the individual grades and the FA has the opportunity to adjust peer values for individual students based on her/his judgment from the knowledge of the students perceived performance and contributions during the semester as well as his/her understanding of team dynamics. The team grade should remain constant in this process.

DETAILED DISCUSSION OF THE GRADING PROCEDURE

The self-directed student teams are forming and consolidating in the first two weeks of class. In the beginning, all PAB members advise all the teams and rotate through meetings with each of the 8-10 teams. A specific adviser is assigned to a team only at the end of the 2nd week and starts to meet with that team once a week in week #3. By the end of week #3 the teams deliver their first report, the Project Definition Document where the teams adapt the customer requirements to the team capabilities. They describe the top level project and system requirements, show that they understand goals, concept of operation, risks, and most importantly their own engineering expertise to bring the project to a successful conclusion. This team document is evaluated by their adviser only.

The team grade is weighted with the following detailed grades for individual components: Background and Peripheral content (10%); Goal and Objectives (15%); Functional Block Diagram and Concept of Operations (20%), Project and System requirements (50%), and Risks (5%). As the adviser has little knowledge of the capabilities of individual students at this point only a team grade is given for the PDD.

The next deliverable, the Conceptual Design Document (CDD) is provided by the end of week #5. At this time the teams have to discuss at least three different architectures of their design which would fulfill the customer requirements. That information has to be analyzed in refined top level project and systems requirements including a revised risk analysis. The team qualification for the project needs to be finalized by this time. The grading of this report is also detailed: Peripheral Content (5%); System Architectures (25%); Requirements revisited (20%); Feasibility analysis (20%); Preliminary Testing and Verification Plan (10%); Risks revisited (10%); Team Qualifications (5%) and Response to PDD comments (5%). The students receive a team grade for this report.

After the CDD the teams focus on one architecture and develop a preliminary design concept. The adviser should have a good idea of the qualifications of individual team members. The next deliverable in week #8 is the Preliminary Design Review (PDR), which is the first oral presentation to the entire PAB and to the entire class. The Preliminary Design Review (PDR) typically marks the end of the preliminary design phase of a project. Teams should have identified the major subsystems and should provide details about specific subsystem options. Students have developed a set of derived system requirements or “Design-To” specifications for the proposed system architecture. These requirements “flow-down” from your top level requirements as stated in the PDD and CDD. Teams identified high risk elements in the project which have critical impact on the overall project success. Special work, such as a prototype experiment or more detailed analysis has to be done on this element. Teams must also consider options for project off-ramps in case they encounter insurmountable difficulties at a later stage. Part of the PDR requirement to the self-directed teams is the delivery of a preliminary project management plan. This includes an organization chart detailing that each team member has to be in one leadership position. The team must also provide a work breakdown structure which will be a living document throughout the project. As each team receives a fixed budget for their

project they have to take financial responsibilities as well and assess the cost of the project carefully.

The grading of the technical content of the oral presentation is divided in several elements (Figure 1): Overview (3%); Objectives (7%); System Options (20%); System Specifications (15%); Subsystem Options (20%); Feasibility and Risks (25%); Project Management (10%). The entire PAB now gives independent grading on all these grading elements. The adviser naturally knows the work of her/his team very well, while other PAB members do know very little about the project. To give the PAB a minimal knowledge of each project the teams are required to blog on a weekly basis on a special network for the course. The technical grade of the PDR is a team grade based on the linear average of all faculty grades.

PDR Grading - AdviserName(replace)

scores: 1 - 5

TEAM	Briefing Overview 3%	Objectives 7%	System Options 20%	System Specs 15%	Subsys Options 20%	Feasibiliy & Risk 25%	Proj Management 10%	Total 100%
#1								0.00
#2								0.00
#3								0.00
#4								0.00
#5								0.00
#6								0.00
#7								0.00
#8								0.00
#9								0.00
#10								0.00
	Is an overview of what will be covered in the presentation provided? Are the team members introduced?	Is a clear motivation and rational for the project provided? Do the project requirements meet the overall goal of the project? Are the requirements clearly motivated? If the PDD requirements were modified, was a reasonable technical argument provided?	Are multiple, realistic potential solutions provided that meet the function requirements (PDD)? Are the key operating requirements for each alternative clearly identified? What are the pros and cons for each choice? Is the complexity, difficulty and feasibility of each solution considered? Are these solutions evaluated using a range of tools including analytical and/or numerical analysis. Is the analysis used to evaluate the possible solutions clearly indicated and are the results reasonable? Is a technical argument made for one of the proposed solutions? Is the resulting system architecture clearly defined?	Are a set of derived "Design-To-Specifications" provided? Do these specifications follow or "flow-down" from the PDD functional requirements? Are these system specifications appropriate given the system architecture?	Is the system broken down into a reasonable set of subsystems? Has the following been done for each subsystem: 1.Are multiple, realistic potential solutions provided that meet the system level "Design-To-Specifications"? 2. Are the key operating requirements for each alternative clearly identified? 3. What are the pros and cons for each choice? Is the complexity, difficulty and feasibility of each solution considered? 4. Are these solutions evaluated using a range of tools including analytical and/or numerical analysis. 5.Is the analysis used to evaluate the possible solutions clearly indicated and are the results reasonable? 6.Is a technical argument made for at least one of the proposed solutions? 7. Is the ensuing subsystem system architecture clearly defined? 8. Has the implication of each subsystem on the other subsystems been clearly considered? 9. If subsystem "Design-To-Specifications" have been provided, are they	Does the project appear to be feasible? Have reasonable technical analyses been conducted? Were multiple measures such as numerical analysis, modeling and spreadsheets used? Were the key areas of risk identified, explained and motivated? Were methods for addressing items of high risk proposed? Was a reasonable item proposed for prototyping?	Does the project have a clear roadmap to success? Does the team have a reasonable organizational structure? Are technical and management responsibilities balanced across the team? Is the proposed schedule through CDR realistic? Is the overall budget realistic? Does the team have a clear work breakdown through CDR?	

Figure 1: PDR-Grading spreadsheet.

The course requirement is that each student on a team has to present at least one time during each semester, which has 2 opportunities in the Fall and 3 opportunities in the Spring. Each student will get a grade on presentation skills. That grade is used to calculate the individual grade from the team grade. A second process to calculate a team grade is the student self-evaluation and the peer evaluation. The self evaluations will be assessed by the adviser. All team members can see the self evaluations of their team members. The peer-evaluation (Figure 2) includes 18 carefully selected questions for which a rating 1- 5 (highest) is given by each student to all his peers on the team. In addition each student can comment on Strengths, Areas Needing Improvement, and General Comments for all her/his team members. The overall score of each student may be adjusted numerically by the adviser after evaluation comments and considering his/her own opinion of the students performance in meetings and the quality of their Notebooks (Figure 3). A scale factor is applied to the individual student grade based on the discrepancies of group/team rating and the adjusted average student rating. If the faculty group grade is lower than the student average rating, then the scale factor, a ratio, is smaller than 1.

This process allows for a straight forward calculation of the individual student grades. After the numerical grade determination for the PDR the PAB convenes to compare grades between teams and individual student performances to understand qualifications of individual students in individual teams. Students receive feedback on their grade from their adviser.

Preliminary Design Review Peer Evaluation

Grading Scale	
0	Never
1	Rarely
2	Sometimes
3	Often
4	Very Often
5	Always

Instructions:
This form is used to evaluate each member of your team for the time interval indicated in the assignment. Before completing the evaluation form you should first review the self-evaluation that your teammate submitted to be sure that you understand their contribution to the team. In the sections of the evaluation from entitled technical contributions and professional contributions you should provide a score between 0 and 5 for each member of your team, the grading scale is provided on the left. Do NOT evaluate yourself, just leave the column blank. The last 3 rows provide an opportunity to provide written comments about each of your teammate. Please use this space to provide some comments which help to provide a context for your ratings. **Once you have completed the review change the name of the tab at the bottom of this spread sheet to your last name and change the string "NAME" in the filename of this excel file to your last name.**

Evaluator: Student 3	Team									
Technical Contributions	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9	Student 10
Has required technical knowledge										
Pays attention to accuracy and details										
Contributes good ideas										
Contributes to the required technical analysis										
Finds information independently										
Willing to get up to speed on new topics										
Understands the overall project										
Effectively troubleshoots problems										
Professional Contributions										
Attends team meetings										
Produces work on schedule										
Effectively takes charge of tasks										
Willing to take on tasks										
Willing to help others										
Communicates clearly with team										
Informs others of teams progress										
Listens to other points of view										
Accepts advice about his/her work										
Gives criticism constructively										
Comments										
Strengths	Always willing to help others	Always has grand ideas that help direct team towards innovative solutions		Hard worker. Has become the expert on her responsibilities	Has helped a lot on integration of components and troubleshooting, even outside of his subsystem	Dedicated to finding solutions to problems, very hard working	Maintains and shares overall vision of project			
Areas needing Improvement	Be more vocal about ideas	Focusing on work at hand, sometimes gets off task or caught up in details		Sometimes seems disconnected from rest of team. Not much systems engineering direction from the systems engineer		Needs to work on identifying exactly what a problem is before moving on to finding solutions	Sometimes dismisses abstract ideas prematurely			
General Comments										

Figure 2: Peer Evaluation Form.

TEAM

Group Grade	4.57					
TEAM	Student Rating (0-5)	Facutly Adjustment	Adjusted Rating	Scaled Rating (0-5)	Grade	
Student 1					0	0
Student 2					0	0
Student 3					0	0
Student 4					0	0
Student 5					0	0
Student 6					0	0
Student 7					0	0
Student 8					0	0
Student 9					0	0
Student 10					0	0
AVERAGE	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
		should remain at 0			Scale Factor:	#DIV/0!

Figure 3: Grade adjustments based on peer and faculty evaluations.

A similar evaluation and assessment of individual grades is done at CDR and in the Spring semester for the Interim Reviews and Spring Project Review, which also include self evaluations and peer evaluations.

Each team produces a Final Report at the end of each semester. These documents are evaluated by the adviser alone as the grading needs to be finished within a few days after submission. The detailed grading for the comprehensive Fall Final Report (FFR) includes (Figure 4): Peripheral Content (5%); Project Objectives and Requirements (5%), System Architecture (10%); Design Alternatives and Design-To Specifications (20%); Project Feasibility and Risk Assessment (15%); Mechanical, Electrical, and Software Elements (25%); Integration Plan (5%); Verification and Test Plan (10%); and Project Management Plan (5%). The notable approach to evaluate individual grades in the FFR is that the assignment requires that each student takes the lead on one major chapter of the report; but can have co-authors. The FFR is used extensively and successfully by the students for job interviews.

FFR 2009 grade on 0-5 score

Team	Front Refs, Writing 5%	Project Objective and Requirements 5%	System Architecture 10%	Development of Design Alternatives and Design-toSpecifications 20%	Project Feasibility and Risk Assessment 15%	Mech, Elec & Software Design Elements 25%	Integraton Plan 5%	Verification and Test Plan 10%	Project & Management Plan 5%	Total 100%	Total/100
#1										0.00	0.0
#2										0.00	0.0
#3										0.00	0.0
#4										0.00	0.0
#5										0.00	0.0
#6										0.00	0.0
#7										0.00	0.0
#8										0.00	0.0
#9										0.00	0.0
#10										0.00	0.0
Average	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Figure 4: Fall Final Report Grading Spreadsheet.

The last element in defining the individual grades is the overall evaluation by the advisers who review the Lab Notebooks of each student on content. In addition the adviser evaluates each student's communication skills and the overall performance based on semester long observations of student participation.

The Fall semester grade is then computed with the following weights: PDD (10%); CDD (10%); PDR (20%); CDR (20%), FFR (20%); Notebook (10%); Student performance (10%). The entire PAB again discusses the final grades of all students to ensure a fair individual grade.

In Spring semester the Interim Review presentations, which serve as an informal briefing for the PAB, are graded by the entire PAB and an average team grade is given for the two presentations. The team grade is not detailed in subtopics. Individual grades are again assigned to students based on student self-evaluation, peer evaluation and notebook evaluation similar to what is done for CDR.

In addition students must write an AIAA Student paper according to the standards set by AIAA. The faculty adviser decides whether the students have a sufficiently high quality to warrant actual submission. Students also participate in a Senior Design Symposium given to attendees from industry. That effort includes a morning session with 5 minutes overview presentations and an afternoon session with poster discussions. Papers and posters are evaluated by the attendees, which will become another metric in the team performance evaluation. A best paper award is given by the attendees.

The Spring Final Review is the last major oral presentation by the teams. The evaluation includes details such as: Overview and Requirements (5%); System Architecture and Component Design (10%); Fabrication and Integration (25%); Experimental Test Results with Verification and Analysis (50%); Project Management (5%); Requirements Verification and Project Validation (5%). Individual grades are calculated from data gathered by the self-evaluations, the peer evaluations and notebooks, similar to the CDR procedure.

The Project Final Report, covering the entire project, but with focus on testing and verification, is again evaluated in details of: Purpose of Project (5%); Revisions from FFR (20%); Fabrication and Integration (15%); Test Plan (5%); Test Results (15%); Test Analysis, verification, Interpretation, Validation (25%); Project Management (10%); and Quality of Documentation (5%). The reports are only evaluated by the advisers to the team and only a team grade will be given due to the very limited time to finish grading.

The Spring semester Final Grade is calculated then from the combined IR (20%); Spring Project Review (25%); Project Final Report (25%), AIAA Student paper and Symposium (15%). The adviser gives a grade on the Lab book and the individual student performance (15%).

This elaborated process is very tedious and tries to be as fair as realistically possible to each individual student. Students that do not proactively participate do not have a chance to drift with the flow. The team dynamics, in general, is very efficient in getting each individual student to participate fully. The quality of the project depends on the overall qualification of each individual student. Therefore it is very important that at the beginning of the project, students document their skills they contribute to the project.

The most difficult part in the grading is the grade comparison between teams. Having only one adviser with detailed insight in one team deprives us from benchmarking performances very well, actually limiting the benchmarking to the oral presentations to the entire PAB. In previous years each team had 2 advisers and each adviser had two teams, which gave these 2 advisers a comparison between three teams which allowed some benchmarking of the given grades. A benefit of that arrangement was also that there are more checks and balances on the individual advisor who could not favor or penalize a team based on personal opinion. However, due to limited faculty resources the dual adviser option was not sustainable, which requires very careful assessments of team, student and adviser performances.

FINAL GRADE CONSOLIDATION

Final Grade Consolidation is done in a meeting of the entire PAB. The goal is to get an understanding of team performance compared to each other. The CC, in agreement with the PAB, may adjust team average grades to reflect the performance quality of teams with reference to each other. The PAB members discuss the grades of all major team deliverables as well as LN and SPE grades given to individual students. FAs may change their initial grades for LN and SPE during this discussion. The PAB makes a major effort in this meeting to recognize the actual performance of all the teams and ensure, as far as possible, fair grading of teams and individual students.

CONCLUSION

In conclusion the grading process described here is satisfying ABET requirements; it is rather fair for most students, but never perfect. In the authors opinion it is acceptable and much better than having a single faculty member handle an entire team without benchmarking by faculty colleagues. The degree of benchmarking can be designed depending on available resources.

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Biographical Information

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