AC 2008-263: AN INTEGRATED APPROACH TO GRADING A MECHANICAL ENGINEERING CAPSTONE DESIGN COURSE AT THE UNITED STATES MILITARY ACADEMY

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An Integrated Approach to Grading a Mechanical Engineering Capstone Design Course at the United States Military Academy

Abstract

Many mechanical engineering departments offer a capstone design course that requires undergraduate students to apply the wide array of theory and skills learned in previous courses. At the United States Military Academy, a key component of the Mechanical Engineering program's capstone design course, Mechanical System Design, is the requirement for each student team to build and test a prototype of its design. Teamwork and open-ended, real-world problems are vital to this course. However, the faculty has had some difficulty in the past assigning fair, objective grades to students in this course for several reasons. One, capstone designs are more open-ended than traditional courses in which grading can be more standardized and objective. Two, capstone design courses tend to be more decentralized and time-intensive requiring the use of many capstone advisors. As a result, there tends to be a wider deviation among graders. Third, many of the tangible results of the capstone process are presented in briefings and not examinations or papers. Grading oral presentations tends to be more subjective than grading written deliverables. Finally, faculty can encounter difficulty ensuring individual grades reflect the quantity and value of individual work and not just the collective grade of the group. This paper outlines the various steps the mechanical engineering faculty took to provide a more standardized, objective, fair grading process in the capstone course. These steps include use of a non-numeric rubric for grading briefings, graded peer reviews, a more objective rubric for grading written documents, and the use of course directors to standardize the grading process.

Introduction

The mechanical engineering curriculum at the United States Military Academy (USMA) includes a capstone design project as a culminating experience that draws on fundamental engineering concepts students have learned in their previous course work. The capstone project requires students to design, build, and test a prototype that satisfies a real-world customer need or qualifies for a competition sponsored by an engineering professional society. The capstone course director, a faculty member responsible for course administration and coordination among course instructors, solicits proposed projects from mechanical engineering faculty members. Once projects with associated funding are finalized, students submit a rank-ordered project preference list. The course director assigns students to projects based on their preferences and any special needs by the projects. Faculty members serve as project advisors and project committee members. Faculty advisors for many years have been the primary assessor of student performance on the capstone project. The challenge lies in assuring consistent grading across projects and recognition of individual student contributions to the project.

Most undergraduate engineering programs include a capstone design experience in their curricula. Capstone projects support meeting the requirements of the ABET Engineering Accreditation Commission (EAC) Criterion 3, Program Outcomes[1]. Evaluation techniques for these projects vary among universities. Many programs require an oral presentation and a

written report, although the actual evaluator varies. Colorado School of Mines[2] requests project clients evaluate the quality of student work presented through written and oral presentations. Wichita State University lean manufacturing project grades are based on instructor-graded oral presentations and written reports and peer evaluations[3]. Until recently in the mechanical engineering program at the USMA, project advisors were the primary graders for project presentations and reports.

Course Description and Sequence

Students begin work on their capstone project during the fall semester of their senior year in the course, Mechanical Engineering Design. In this course students learn the formal steps of the design process with its associated tools and considerations. Initial work on the capstone project begins after formal instruction ends midway through the semester. The goal is for students to reach the detail design phase, develop a bill of materials, and order parts and raw materials prior to the end of the semester.

The students continue work on their capstone projects in the spring semester in the course, Mechanical Systems Design. No formal instruction takes place in this course. Students build their prototype, conduct testing, and redesign and rebuild as required. Competition projects normally compete in April/early May. Projects culminate with formal presentations and prototype demonstrations during the Academy-wide Projects Day in May. External judges evaluate these presentations to determine the winner of the "best capstone project" award. Students submit a final report by the end of the semester. Additional major graded course requirements include a project web page, a mid-term oral presentation, and a project poster.

Problems Encountered in Previous Course Offerings

In a national study conducted on capstone design courses and the assessment tools used in those courses, two themes emerged. One, most engineering schools consider capstone courses that feature open-ended, engineering problems to solve as vital to assessing the outcome of most if not all of the ABET program outcomes. However, the study also revealed that only 40% of faculty members felt that their assessment tools were "detailed in nature"[4].

The capstone courses offered in the mechanical engineering program were no different than those in the national study, with respect to the above findings. During previous course offerings of the capstone design course, faculty encountered several problems ensuring students received fair grades that reflected their level of effort and achievement. The problems mainly stemmed from the dilemma between ensuring grades were consistent and linked to objective standards while simultaneously capturing input from project faculty advisors and allowing student design teams a high degree of freedom and individuality in their projects.

Grading Consistency

Earlier course offerings put much of the grading responsibility in the hands of the faculty advisor. The belief was that the advisor had the best sense for the amount of work the team conducted and the degree to which the team members met their design goals. Each student design team had one or at most two faculty members who served as the primary advisor and

sponsor of the design project. Often, this faculty member obtained approval for the design project, sought external funding when necessary and was a subject matter expert on the project. As a result, the faculty advisor had a vested interest in seeing the design project succeed. Many of the design projects were in response to student design competitions or real-world needs. For example, cadet teams in the past designed projects to assist handicapped people perform their jobs in the workplace while other teams addressed design needs for soldiers engaged in the Global War on Terror.

There were two issues associated with placing a large portion of the grading responsibility on the faculty advisor. First, there was a lack of consistency among advisors. In a typical capstone design course offering, there were roughly 15 design teams with 15 different advisors. Each advisor naturally had a predisposition as either an 'easy' or 'tough' grader. Therefore, the teams with advisors who graded their students more leniently benefitted from their association with that advisor. Normalizing techniques were insufficient to alleviate the inconsistency in the grades because the advisors did not grade all of the teams. Therefore, there was no way to tell if high or low grades were a result of the grader's predisposition or the quality of the team's submissions.

The other problem the faculty encountered was the inability of some advisors to objectively grade the work of a team with which they had such a strong association. As mentioned previously, each advisor worked closely with the design teams and tended to have at least a subconscious desire to see the team succeed. Some advisors appeared unable to give their team a low grade, perhaps because they felt that a low grade was indicative of a failure on their part as an advisor to mentor or assist the team appropriately. Therefore, the overall grades for the course were usually very high.

Table 1 shows the mean grade point averages (GPA) for students before they took the capstone design course and the mean GPA for the course over a period of ten years. One can see from the data that the students taking the capstone design course received substantially higher grades than they were accustomed to receiving previously. There was substantial discussion among the course designers about the cause of this grading discrepancy. Clearly, there is a belief that students will work harder and put more effort into a design project for which they take ownership and feel is relevant. Another possible contributing factor is that the team aspect of capstone projects creates synergy that allows the students to outperform their individual levels. Research indicates the positive effects of cooperative learning on student performance[5].

While it is impossible to determine the effect that working as a team on a desired project has on student grades, one piece of data was available. In previous course offerings, grades were available for design presentations from the faculty advisor and committee members who were assigned to specific groups and worked, to some degree, as secondary advisors. Committee members were not as closely aligned with individual teams as the advisor. In every graded event for which data was available, the average of the faculty advisors' grades for a presentation was higher by four to seven percentage points than the average of the committee members. This fact led the course directors to believe that there was some connection between the higher course grades in previous offerings and the close connection between the teams and their faculty advisors.

Table 1: Course Grades for Previous Offerings

Term	Incoming GPA	Course GPA	Delta
97-2	3.04	3.57	0.53
98-2	3.10	3.98	0.88
99-2	3.11	3.98	0.87
00-2	3.08	3.84	0.76
01-2	3.20	3.90	0.70
02-2	3.21	3.86	0.65
03-2	3.13	3.83	0.70
04-2	3.14	3.61	0.47
05-2	3.03	3.94	0.91
06-2	3.23	3.94	0.71

Evaluating Oral Presentations

Another issue related to grading consistency was the outcome of grading oral presentations. Presentations were a vital aspect of the capstone design process and allowed the faculty the opportunity to assess the ability of the students to achieve ABET EAC outcome (g), an ability to communicate effectively. In previous course offerings, advisors and capstone committee members were issued grading sheets to evaluate oral presentations. Using a rubric, the faculty members evaluated various aspects of the presentation using a numbered scale and then added the point values to determine an overall grade.

However, many advisors and committee members already had a personal interest in the success of their group. As a result, graders tended to select a final grade for the presentation and then tailor the grades for individual sections on the rubric to ensure the sum of the individual parts matched the final grade for the presentation. Unfortunately, this did not provide team members with the most accurate feedback on their performance in the different components of the presentation.

Evaluating Individual Team Member Contributions

The last issue regarding grading a capstone design team project was the ability to acknowledge the difference in the level and quality of work by team members. The teams typically ranged in size from three members to as many as ten members based on the level of difficulty of the project. Advisors often received informal feedback from student team leaders and team members that specific individuals were not contributing effectively to the project.

The dilemma for the faculty advisors remained how to reward those individuals who were contributing the most to the success of the project and provide feedback to team members who were not contributing as much without spending an excessive amount of time observing the team

dynamics. A key component of the capstone design process was to allow the student teams a great degree of autonomy in their work so that student members could gain valuable experience in leading and working as a team. The result of previous course offerings was that the team members who contributed more to the project often felt frustrated that they received the same grades as those who did not contribute as much.

Methods Introduced in Academic Year 2007 to Increase Objectivity of Grading

To address the three major issues discussed above, the course director for the capstone design course instituted four changes to the evaluation process. While none of the changes is new or unique, the combination of the techniques used to evaluate the capstone course was different from any of the program's previous course grading methods. The changes were designed to achieve several goals. The grading system had to ensure that faculty advisors, due to their expertise and familiarity with the project, still provided feedback and evaluation to the teams. On the other hand, the grades had to be balanced and standardized to ensure that all students in the course received fair grades that reflected the quality of their work relative to the other teams in the course. In addition, the new grading system had to provide more honest feedback for the oral presentations. Finally, any changes needed to provide a means to reflect the varying levels of contribution to a project by the team members. Because these changes increased administrative and grading demands on the course director, an additional faculty member served as assistant course director.

Grading Responsibility

To add more objectivity into the faculty evaluation process in the 2007 course offering, the course directors combined three techniques: distribution of grading responsibilities, use of grading rubrics, and introduction of non-numerical evaluation. The first technique involved splitting the grading responsibility for grading written project submissions between the faculty advisor and the course director. For each written submission, the faculty advisor was responsible for approximately 50% of the submission grade and the course director took responsibility for the remaining portion. Instead of evaluating the same learning objectives, the two faculty members focused on distinct aspects of the written submission more appropriate to their areas of expertise. For example, the course director typically graded written submissions based on the application of the mechanical engineering design process to the project in question. On the other hand, the faculty advisor evaluated the technical merits of the project and the consideration of real-world inputs and constraints.

The advantages of distributing the grading responsibilities in this manner were three-fold. One, this technique took advantage of the different areas of expertise of the faculty members. The course directors had a firmer understanding of the engineering design process because they had taught the process during the pre-requisite course. On the other hand, the advisors had a better understanding of the technical aspects of each separate project due to their close association with the team.

Two, the course director was able to provide a normalizing effect on the student grades by evaluating every project in the course using a consistent grading scheme. This approach mitigated some of the variability and bias associated with having the faculty advisors solely

grading their own projects. The third advantage in this approach was that the course director was able to evaluate the quality of each project submission relative to the other submissions in the course. Previously, each individual project advisor lacked this global perspective. Thus, the course director was able to work with each faculty advisor to highlight areas for improvement in those teams that lagged behind their peers.

Grading Rubrics

In conjunction with the distributed grading responsibilities, the course directors developed a more objective grading rubric for use by the faculty advisors and course director. In the previously mentioned national study on capstone assessments, many rubrics observed in the study on capstone assessments remained subjective[4]. Felder and Brent discuss the value of using a well-defined rubric to reduce the amount of subjectivity when assessing student outcomes[6].

The rubric split the responsibility for grading into distinct areas and provided a more objective grading scale based on standards for each area. An example of a portion of the rubric appears in Figure 1. It shows a section of the grading criteria for a written report. While not completely eliminating the subjectivity inherent in grading a design project, the rubric did alleviate some of the variability associated with the more open-ended grading used in previous course offerings. The course director wrote the grading standards directly into descriptions of the various entries of the rubric to explain to the faculty advisors and students the standards expected in each section of the report.

Discussion of Tasks Remaining (25 pts): This section should address remaining relevant tasks. For each task the report should describe the task, what needs to be accomplished, the timetable and strategy for each task, any risks in completing the task, and the approach for completing the task.

- 22-25 pts: Includes a comprehensive explanation of each remaining task and all of the above criteria.
- 16-21: Includes a partial explanation of each remaining task and all of the above criteria.
- 10-15: Includes a minimal explanation of each remaining task and all of the above criteria.
- 1-9: Does not include an explanation of each remaining task and all of the above criteria.

Figure 1: Rubric Example

The use of rubrics, as described above is similar to the use described by Powe and Moorhead in their 2006 article on the use of rubrics to grade laboratory reports[7]. Their combined use of quantitative and qualitative methods in their rubrics helped standardize the grading of reports by teaching assistants who each had to grade reports for a common course. In the same manner, the faculty advisors in the senior design course each had to grade the design report for their individual team, while submitting that grade for a common course. An additional benefit that Powe and Moorhead identify is that the use of rubrics in this manner shortened the time to grade reports when compared to using completely holistic or non-structured approaches. One additional piece of advice from this article that could be incorporated into the design course is the collaboration with faculty members in the English department to create rubrics that further emphasize writing skills.

Non-numerical Evaluation

Another technique the course directors introduced to the design course was the use of non-numerical grading sheets to evaluate oral presentations. Previously, the course used numerical rubrics that used a point scale to evaluate various aspects of the presentation. Anecdotal evidence indicated that advisors and committee members were determining an overall grade and then using the sections of the rubric to ensure the sum matched the presentation grade. Unfortunately, this method did not provide teams with accurate feedback on all of the sections of their presentation.

To remedy this problem, the course directors introduced a presentation rubric that retained the various sections previously used. Instead of numerical values, the sections featured adjectives to describe the performance on each section. While this technique retained a degree of subjectivity, it precluded graders from being concerned with the final presentation grade and allowed them to concentrate on feedback. The course directors assigned a numerical scale for each section based on the adjectives, but the scale was not divulged to the graders before the presentations. After consolidating the feedback sheets, the course directors converted the results to a numerical grade. An example of a grade sheet used for presentations appears in Figure 2.

CONTENT	**RANGE: Circle one. If briefing falls between two descriptors, circle both (i.e. between good and excellent)**
Overview: Introduction, Outline and Background sufficient to explain scope of project	Poor – Marginal – Fair – Good - Excellent
Application of Proper Engineering and Scientific Principles: Appropriate use of underlying physics and modeling	Poor – Marginal – Fair – Good - Excellent
Proper Application of Design Process: Appropriate engineering design tools applied	Poor – Marginal – Fair – Good - Excellent
Applicability to Society: Recognition of social, political, economic, technological impacts	Poor – Marginal – Fair – Good - Excellent
Presentation Structure: Logical outline, appropriate topics addressed, sufficient coverage of design phases	Poor – Marginal – Fair – Good - Excellent
Quality of Final Product: Level to which customer would desire final product	Poor – Marginal – Fair – Good - Excellent
Conclusions and Recommendations: Lessons learned, conclusions based on facts	Poor – Marginal – Fair – Good - Excellent
DELIVERY	
Effective Communications: Clearly communicated technical material to non-technical audience, elicited audience interest, appropriate use of visual aids	Poor – Marginal – Fair – Good - Excellent
Delivery: Proper volume, distinct pronunciation, timing, confidence in delivery, showed enthusiasm, proper body language	Poor – Marginal – Fair – Good - Excellent
Discussion/Answers to Questions: Confident in response to questions, able to think under pressure	Poor – Marginal – Fair – Good - Excellent

Figure 2: Non-numerical Presentation Grade Sheet Example

Peer Review Grading

The last grading change introduced to the capstone design course in 2007 was the use of peer review grading for the major assignments. The directors used this tool to help differentiate grades between students who contributed more or less to the success of the project without forcing faculty advisors to be responsible for monitoring their teams at all times. Thus, the teams still enjoyed significant autonomy while maintaining accountability within the teams and providing students a means to enforce an equal workload. Although there is not enough research to clearly outline the benefit of using peer assessments, there is enough information in literature to indicate that group projects also require some degree of individual accountability[5].

After submitting major assignments, the students completed a matrix that featured all of the team members' names including their own. The team members determined the relative contribution of each person relative to the entire workload. The result was a value that represented the percentage of the entire workload each member contributed. The course directors calculated the mean contribution of each team member and compared it to the theoretical even share based on the team size. For each major assignment a corresponding number of points was associated with the peer review. Each team member could receive more or less than this point value based on the results of the review.

For example, on a team with four students each member should contribute 25% of the workload. If one team member only contributes 20% of the workload, then that student would receive 80% of the peer review points associated with the assignment. Since this method is a zero-sum proposition, other team member(s) on this team would receive more than the allotted points because they would have contributed more than their theoretical share of the work. This was a way to provide limited extra credit to those team members who, because of their leadership role or work ethic, carried more responsibility for the team.

Results of Changes Introduced in 2007

Overall, the grading changes made produced positive results. Each change presented advantages as well as minor disadvantages that will be discussed in more detail. However, combination of the four changes made in 2007 produced a much different result in the final course grades. Compared to the previous ten years, as depicted in Table 1, the final course grades in 2007 featured a course GPA much closer to the mean GPA of the students entering the course. While it was not the goal of the course directors to arbitrarily reduce the students' grades, the changes introduced appear to have tempered the impact that the natural bias of the faculty advisors created in previous years. The fact that the course GPA still was higher than the average incoming GPA is most likely due to the fact that the students are working in teams on projects that they chose and that gave the students an opportunity to apply engineering in a hands-on manner.

Table 2: Course Grades for 2007 Offering

Term	Incoming GPA	Course GPA	Delta
07-2	3.24	3.59	0.35

The second indicator of results from grading changes appears in Figure 3. The chart shows the results of student comments on their formal course assessment offered every year. The question asks students to rate the feedback they received on assignments during the semester on a scale of 1-5. The data shows no appreciable difference in the student assessment received during 2007 and the previous four course offerings. This assessment offers mixed conclusions about the grading changes. On one hand, despite the lower course grades in 2007, students still felt that they received timely and accurate feedback on their work. In other words, there was no negative backlash due to the more realistic grading in 2007. On the other hand, the student perception about the quality of the feedback they received did not seem to change with the use of the new techniques. The meaning of the lack of change in student perception will be discussed in detail in the Conclusions and Recommendations section.

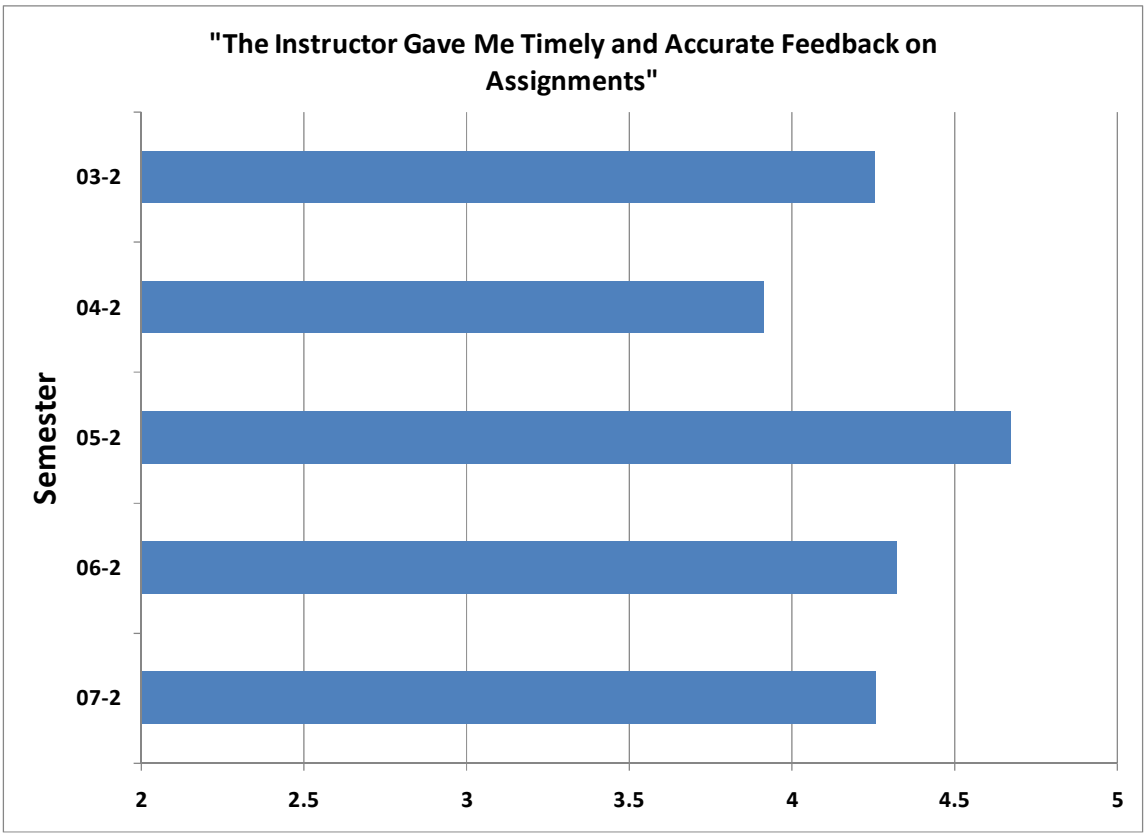

Figure 3: Student Course-end Comments on Instructor Feedback

An example of results from distributing grading responsibilities and utilizing a more objective grading rubric appears in Figure 4. The chart shows the grades assigned to the project teams for their final report submission in the course. On the left axis is the percent grade that the faculty advisor and the course director assigned to each project. The right axis is the scale for the difference between the two grades.

This analysis reveals two results. First, there is a close correlation in the type of grades assigned by the course director and advisor. Clearly, there were no major disagreements regarding the quality of the assignment. Second, the course director's grade was, on average, five percentage points lower than the advisor's grade. This difference in grades occurred

whether the course director or assistant course director was the primary grader for a particular graded event. This fact appears to corroborate the belief that the faculty advisors tend to assign higher grades based on their closer connection to the project team. While this chart only features one assignment from the course, other assignments throughout the course exhibited these general trends.

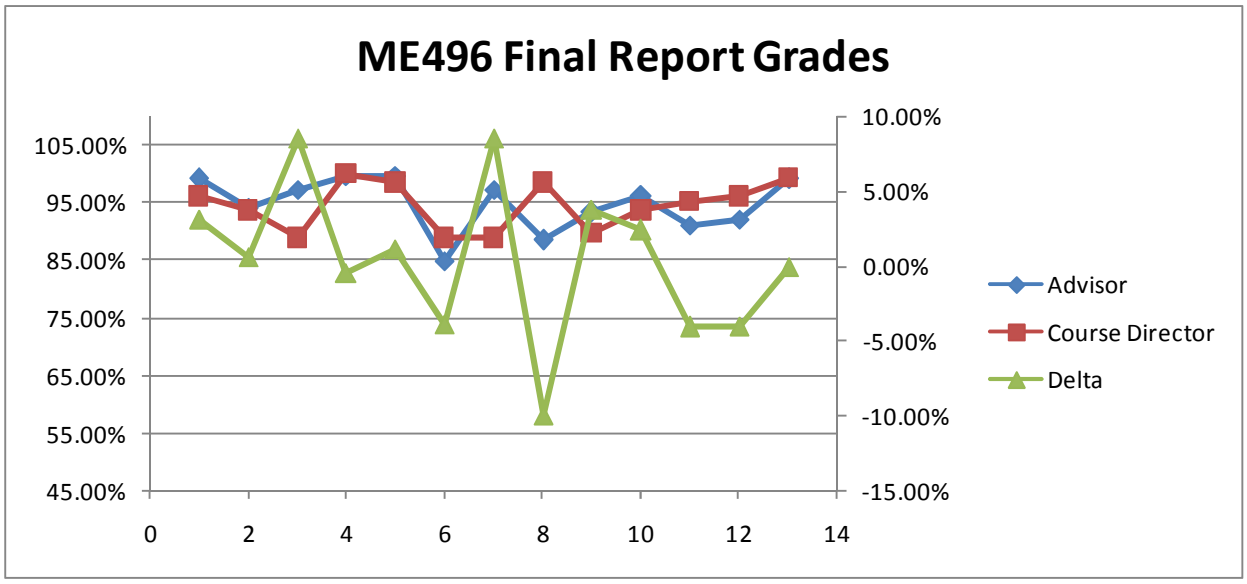

Figure 4: Advisor and Course Director Grades for a Typical Assignment

The results from the non-numerical presentation grade sheets were illuminating. Again, the non-numerical grade sheets, an example of which appears in Figure 2, were designed to provide students more accurate feedback on each portion of their presentations. They were particularly designed to reduce the chance that graders would develop an overall grade for the presentation and then fill in the various sections to sum to the final grade.

Despite graders using adjectives instead of numerical values, the results of the numerical conversions were very similar for each presentation. On average, the amount of deviation from the mean grade for each presentation was approximately 5%. This value is nearly identical to the difference in average grades between the course director and faculty advisors when using a numerical rubric to grade written submissions. Thus, the use of non-numerical grading rubrics did not create a large deviation in the grades assigned to each presentation and in fact, created a more honest assessment of the presentations.

Finally, the use of peer review grades was successful during the 2007 capstone course. The total peer review points available consisted of 6.25% of the overall course grade. This value is for one course. The students had two opportunities to provide peer feedback. The first opportunity was worth 25 points and the second opportunity was worth 75 points for a total of 100 points in a course worth 1600 points. The first opportunity occurred after the first major deliverable requirement. The purpose of that peer review grade was to provide the team members with an initial assessment of their contributions so that if problems were identified, they could be addressed before the end of the course. While not a major portion of the course

grade, there was enough weight available to change a student's course outcome by up to half a letter grade. In fact, there were many instances in which the peer review grades did just that.

The course directors did make one observation about the patterns associated with team peer review grades. The size of the teams in the course ranged from three to ten students. Of the fourteen capstone teams, four teams had three members, five teams had four members, two teams had five members, two teams had six members, and one team had ten members. Teams with five or six members had the least deviation in the grades assigned each other. Those teams felt that most people on the team were contributing to the project appropriately. On the other hand, smaller teams and larger teams exhibited larger deviations in how they rated their peers. The amount of peer grade deviation based on team size appears in Figure 5. One fact to note is that there was only one team with ten members, so the data for teams with ten members may be unreliable.

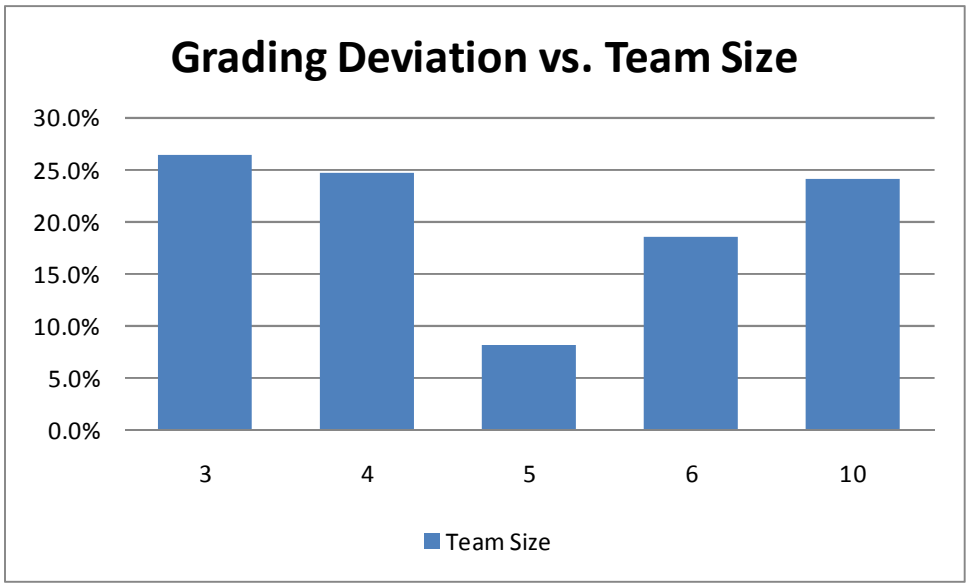

Figure 5: Peer Grading Deviation vs. Team Size

A few reasons explain these results of the peer reviews. First, on larger teams there is much more opportunity for social loafing and peer reviews reflect that fact. The team with ten members often was unable to meet with the entire team in one place and the workload distribution led to several of the team members carrying a larger portion of the project. On the opposite end of the spectrum, the teams with only three members were primarily formed to work on projects that were not the first choice of the majority of the students. As a result, many of the three-member teams were selected by the course directors and not the students, unlike the rest of the teams. The data reflects the dissatisfaction of the three-member teams with their project. In addition, if a member of a three-person team does not contribute equally to a project, the effects are felt much more keenly than would be with a slightly larger team that can absorb the extra work more easily.

Finally, it does appear that five-member teams were the optimum size for the projects offered in the capstone course based on student satisfaction with their peers' contributions. Due to the

scope and workload associated with the capstone projects in this course, five members were adequate to accomplish the task while remaining small enough to discourage social loafing.

Conclusions and Recommendations

As a whole, using the grading techniques described in this paper was successful. The techniques diminished the amount of subjectivity inherent in grading design projects. They also reduced some of the bias associated with faculty advisors solely grading their own project teams. The peer review provided students with a means to encourage fellow team members to contribute equally to the project. The course directors also were able to provide an assessment of each project relative to the other teams as a result of grading some portion of each submission.

The student perception in Figure 3 that the timely and accurate feedback in the course did not change relative to other course offerings can most likely be explained by the duality of the question offered on the student assessment tool. The question asks students if they received timely and accurate feedback from their instructors. While the students received more in-depth feedback in the course from two different faculty members, the feedback process was often less timely. One disadvantage of having the course director and faculty advisor grade each submission is that the grading process took longer. Therefore, some teams did not receive feedback on assignments as quickly as others. Splitting the grading responsibilities between the faculty advisor and course director did not change the grading workload for the faculty advisors. However, by adding another grader to the process the time spent grading each project was effectively doubled. For the course director or assistant, grading 15 submissions of one report could amount to as much as 30-45 hours of work. Obviously, this is a significant amount of work if the course director is also involved in another course, administrative work, and is a faculty advisor as well. However, the benefit of having one individual provide a common frame of reference for evaluating all of the projects outweighed the disadvantage of the time requirement, in the view of the faculty involved in the course. One way to mitigate the workload was to alternate grading major deliverables between the course director and assistant course director.

For future course offerings, the directors should do several things. One, the overall approaches to grading outlined in this paper should be retained. The advantages gained by using these techniques definitely outweighed any disadvantages. To further refine the process, the course director should add slightly more detail to the grading rubrics and make the rubrics available to students early in the process. This will create more detailed feedback for the students and ensure that they know the standards earlier in the course.

The course directors should carefully analyze the grading rubrics to determine if they are as detailed as necessary and clear enough to reduce subjectivity in the assessment process. During the 07-2 semester, many of the grading rubrics were used for the first time. Feedback from the grading process that identifies any problems associated with the descriptors for each assessment area, point values, or other aspects of the rubric should be addressed.

In addition, the course directors should analyze the workload expected for each project and choose the team size more carefully. The peer review feedback indicates that there may be an

optimum team size for these projects. Ensuring that the team size accurately reflects the workloads expected will make it more likely that the students are all able to contribute equally and effectively.

One way to improve the peer review process is to provide more feedback to the team members. A method to accomplish this goal is to require the students to assess their peers' contributions in several distinct areas of the project to include research, building, testing, and preparing deliverables[8]. Instead of simply receiving one grade based on the assessment of their peers, students would be able to determine what aspects of the project in which their peers felt they were stronger or weaker.

Ultimately, the capstone design process is a critical component of any engineering program. Assessing the outcomes of these courses is a vital part of assessing the overall strength of each program. Devoting time and thought to developing clear, objective, and standardized grading tools is necessary to ensure success.

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