Grading Capstone Designs: On Time and On Target

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Abstract

ABET criteria, emergency response and prevention, and an ever increasing demand for impacting the production schedule is accelerating the need for engineers to become broad-based leaders instead of just highly trained technicians. In order to prepare engineering students for such an environment, design courses are more routinely requiring students to complete open-ended, real-life design problems. Such problems require a different grading process than those that have an easily defined solution. This paper explains how, through the use of a blended criteria and norm based assessment and evaluation process, to clearly communicate standards and outcomes, fairly grade dissimilar designs, and effectively encourage continuous improvement of design products. Evidence of these outcomes will be assessed through the statistical analysis of student feedback from the United States Military Academy.

Introduction

United States Military Academy (USMA) civil engineering majors are required to complete a one-semester capstone design project as a requirement for graduation. The capstone design provides the best integrated experience to assess student performance on the USMA Civil Engineering program objectives listed in Figure 1.

Civil Engineering Program Objectives Supported by the Capstone Design

- Application of engineering thought process to design CE components and systems
- Creativity
- Proficiency in structural engineering
- Proficiency in environmental engineering
- Proficiency in hydrology & hydraulic engineering
- Proficiency in geotechnical engineering
- Proficiency in mathematics
- Proficiency in calculus-based physics
- Functioning on multidisciplinary teams
- Understanding and performance of roles and responsibilities of civil engineers and the issues / professional practice
- Use of modern engineering tools necessary for engineering practice
- Effective writing
- Effective speaking
- Broad education /understanding of the impact of engineering solutions in a global/societal context
- Preparation for and willingness to pursue continued intellectual and professional growth

Figure 1. CE Program Objectives Supported by the Capstone Design

The process of developing, administering, and evaluating a civil engineering capstone that contains the breadth, complexity, and challenges necessary to achieve the above objectives is certainly not trivial. Furthermore achieving objectives does not simply imply ending the capstone design with at least a passing grade. ABET tells us in its first criteria "The institution must evaluate, advise, and monitor students to determine its success in meeting program objectives."[1] Creating and administering a capstone design that fulfills this ABET criterion and meets the programs objectives can easily overwhelm faculty as well as students. The associated frustration typically puts the faculty and students at odds with one another resulting in each side just trying to survive the capstone project rather than the project capping the students' four-year educational experience with a quality product and learning event. To prevent this, we carefully craft our design problem with an appropriate mix of real-world and academic parameters that make the design problem realistic, demanding and open-ended, yet understandable to a junior engineer. While creating such a design project each year is challenging even to the most experienced faculty, assessing and evaluating student performance on such a project is even more difficult. Dutson, Todd, Magleby, and Sorensen in their paper on capstone designs remind us, "One of the most difficult assignments for instructors of capstone courses is the evaluation of student performance and the distribution of grades."[2] Without a good assessment and evaluation system even the best thought out design problem will not fully realize its potential to culminate an engineering student's undergraduate experience, and it will fall short of supporting ABET's first criterion. Whereas, the pairing of a well designed capstone problem and a carefully planned assessment and evaluation system will empower both students and faculty to make the most out of a capstone design experience while achieving all the requirements for accreditation.

Capstone Project Development

To create a capstone design that supports our program objectives, we base our problem statement on a structure that is planned to be built in or near the USMA community. Designing for an actual need gives our students a real-world feel for their design and allows instructors to adjust a given scenario to meet program requirements rather than create one from scratch. A couple of our past capstone design projects have been an equestrian facility, a water treatment plant for the surrounding community and a chapel annex for religious education.

To develop the project, we perform an initial interview and fact-gathering phase prior to the beginning of the semester-long capstone course. During the fact-gathering phase, we define the general scope of the project and give students and faculty a basic understanding of the physical, cultural, economic, and political implications of constructing the structure. To summarize this initial study, the course director of the capstone design course produces a pamphlet of information (historically called a 5% design or design guidance) for distribution to the students and faculty involved in the project. Many times this document is prepared as a result of an independent study project done by a small group of students during the previous semester or academic year.

In conjunction with the initial study and production of the design guidance, the course director prepares an administrative memorandum that outlines the schedule of turn-in dates and products required throughout the semester. This memo attempts to clearly communicate what is required and when it is required. The required submissions mirror the familiar 10%, 35%, 65%, and 100% design submissions. It also contains scheduling information and guidance for the required briefs to clients, faculty and peers.

The two documents described above help the faculty communicate requirements to students and to each other, while placing a loose frame work on what is otherwise a wide open capstone design. We expect our students to take customer requirements, a piece of land, knowledge from their previous courses, and our guidance described above and use it to produce a product that will suit the customer's needs, posses sound engineering, and consider local and national code requirements. We expect this product to contain the basic elements of appropriate architecture and site layout, as well as be sensitive to environmental, political, cultural, economic and social concerns. Additionally, we expect very detailed, well planned, and appropriately communicated structural, geotechnical/foundation, environmental, and hydrologic plans.

Capstone Project Assessment and Evaluation

Developing a good design problem is very important; however, even more important is assessing and evaluating student work throughout the design process. After all, our primary purpose in the capstone design is not to produce an engineering product, but to prepare engineers to produce products. As faculty we need a system that efficiently assesses our students' design process and products as the semester progresses, serves to help us continuously mentor them throughout the course, and culminates in a clear evaluation of their final product. This led us to develop an assessment and evaluation system for our capstone design that is both easily understood and implemented by students and faculty alike. Our system is designed to achieve the following goals: clear communication of standards, fair evaluations of very different solutions, clear communication of outcomes, and encouragement of follow-up/corrective work.

We use a system that blends a criteria based grade sheet and norm-based comparison of grades to achieve these goals. At the system's core is an analytic-criteria[3] based 10-point scale for each component of a submission. Each component is then weighted relative to other sections in the design submission by assigning a weighted point value to the section. This system is completely scalable and flexible. Our system maintains an appropriate level of grading consistency between designs from group to group and year to year. Additionally it gives faculty the flexibility to adjust the relative importance of each aspect of the design as required by the unique requirements of each year's design and talents of that year's group of students. See Figure 2 for a grading sheet using this system for our capstone's 10% submission. During the capstone project, at least two instructors grade each submission using the criteria based grading sheets. After the grading sheets are complete with grades and free-form comments, the course director records the scores for each section and looks across the course in each portion of a submission to assess the effort and results between groups. The course director will assign a final grade for the submission using both this norm-based comparison and the criteria based grading sheets.

The final grading sheets are returned to the students with their graded submission to close the assessment loop. The students are then free to use this feedback to discuss strengths and weaknesses among themselves as well as with faculty. Additionally, the course director maintains copies of these grade sheets and uses them to compare student progress in any given

CE492 ENGINEERING DESIGN PROBLEM TERM 02 -2
10% SUBMITTAL GRADE SHEET

Total Value of Design Submission

GROUP # **Name** ______________________________________
GRADE _____/200

Team Bonus Points Earned ______

OVERALL QUALITY OF REPORT - ____/10: ____/10 Points

Title Page, N arratives, Tables, Figures (sketches): Neatness, Layout , Format, and Readability.
Terms defined. Documentation.

REPORT MAIN BODY – 35 POINTS

Common 10-Point Scale

____/10: ____/5 points. PROBLEM STATEMENT or SCOPE: Who you are, why you are involved, and what you wish to accomplish.

____/10: ____/5 points. FACTS and ASSUMPTIONS

____/10: ____/25 points. NEEDS ANALYSIS

FUNCTIONAL REQUIREMENTS. (Primarily, what you were asked to provide and important information needed to accomplish the design):

Discussion & tables as necessary for:

- Overall site requirements (#rings, sizes, bldg, lights, watering, etc.)
- All rooms with description and required gross square footage (GSF) are shown
- Adjacencies table and/or diagram
- Access/Egress
  - Location of doors, windows
  - Personnel incl. handicapped
  - Equipment (traffic routing)
- Special Equipment (sizes and locations, washing machines,etc.)
- Parking
- Utility requirements
- Zoning and Easements

AESTHETICS

- Exterior appearance, texture, color, windows and doors
- Interior features
- Match surrounding area

APPENDIX A: SITE RECONNAISSANCE REPORT - ____/10, ____/30 Points
Reference: TM5-803-14, section 3-3

Completeness, Accuracy, Sketches, Dimensions, Clarity, Sources

Off Site Condtions

- Surrounding Land Use
- Transportation
- Utilities
- Environmental Conditions & Hazards
- Historical & Archeological Issues
- Safety Hazards
- Physical Security
- Sources of Air, Noise & Light Polution
- Visual Context

On-Site Conditions

- Geology
- Topography
- Hydraulogy
- Soils
- Climate
- Micro-Climate
- Vegetation
- Wildlife Habitat
- Historical & Archeological Issues
- Visual Conditions

Weighted-Point Value of Section

APPENDICES B-D (ARCHITECTURAL CONCEPT) -60 Points

____/10: ____/15 points [APP. B] SITE PLAN (ref: TM5-803-14, chapt 5)

- Easy to identify the orientation
- Footprint of building, pitch location, lighting shown
- Access to building/mechanical room shown
- Vehicle circulation (roads) and parking lot (# spaces & sizes incl. handicapped)
- Equipment access/egress (traffic lanes and routing plan)
- Pedestrian Circulation and sidewalks
- Utilities
- Drainage structures
- Landscaping, trees, bushes
- Topography
- Practicality
- Site Amenities (what did you do to make it nice, special, classy?)

____/10: ____/15 points [APP. C] DRAINAGE

- Separate sketch of drainage pattern given
- Shows areas outside the site which will send water to the site
- Plan to reroute water around/under/through the site
- Flow lines near pavement and the structure make sense as ditch & culvert locations
- Identification of water generation & pattern on the site
- Identification of major drainage structures required: drop inlets & culverts
- Final direction of water shown

____/10: ____/15 poi nts [App. D] ARCH. CONCEPT: EXTERIOR ELEVATIONS

- Size and form of building shown for all sides
- Windows and doors properly sized and positioned
- Exterior wall consistent with USMA Installation Design Guide

____/10: ____/15 points [App. D] ARCH. CONCEPT: FLOOR PLAN

Building outline not unnecessarily irregular
Location of all rooms, doors, windows, lockers, conveance, and walls shown
L/W ratios not excessive
Hallways and corridors
Exits and corridors configured IAW building code standards
Handicapped access throughout building
Room dimensions meet size, spacing, and access/egress door requirements

APPENDICES F-L (STRUCTURAL SCHEME) -35 Points

____/10: ____/10 points [App. F] ROOF FRAMING PLAN

- Concept of roof system stated/sketched
- What's roof made of?
- Fits the floor & column plan
- Spacings resonable
- States information that will affect roof

____/10: ____/10 points [App. G] FLOOR FRAMING PLAN

- Floor framing concept stated/sketched (rolled or joists, orientations)
- Floor concept (concrete, deck, precast?)
- Fits with roof plans
- Spacings reasonable
- States any information that will affect floor

____/10: ____/5 points [App. H] COLUMNS

- Column spacing reasonable
- Column orientation shown and consistent with lateral load resisting system
- No columns in open spaces
- Column placement does not interfere with riding area, rooms, windows, or doors
- Columns placed on a regular grid when possible
- Column lines labeled

____/10: ____/10 points [App. I] LATERAL LOAD SYSTEM

- LLCS concept stated and appropriate for structure
- LLCS elements reasonably located (doesn't interfer with openings and labeled)
- LLCS reasonable and practical
- Placement of lateral bracing prevents torsional problems in the structure
- Column orientation is consistent with LLCS

APPENDICES J-M (INTIAL DESIGN RELATED ISSUES) -30 Points

[App. J] **Connections** (not required on 10%)

____/10: ____/4 points [App. K] Wall Concepts

- State information impacting wall systesms
- Possible discussion of potential wall systems under consideration

____/10: ____/4 points [App. L] Foundation Concepts

- State information impacting foundation systesms
- Possible discussion of potential foundation sy stems under consideration

____/10: ____/7 points [App. M] Cost Estimate

- Estimates calculated IAW RS Means references
- Square foot costs are reasonable
- Total cost is reasonable

____/10: ____/3 points [App. Q] Historical Tie-in

- Brain storming how to do this
- Pictures of ideas

____/10: ____/2 points [App. ?] ?

- Whatever else needs to be included

____/10: ____/10 points [App. Z] Documentation

- GO/NO GO for meeting minimum standars of DWW
- Bibliography including BCI, Codes, USMA Documents, pla ns, stuff from folders
- Note numbers, parenthetical documentation in main body
- Quality of MFRs and other records of meetings

Figure 2. Grading sheet for 10% submission of capstone design

area as the design progresses. By using this system, we have clearly communicated our standards, made every effort to fairly evaluate student work, clearly communicated outcomes, and put into place an accurate record that can be used to adequately reward follow-up and corrective work. Let's look more closely at how our system achieves each of these four goals.

Clearly Communicating Standards

Clearly communicating faculty expectations to students begins with the development of the design project and continues through the assessment and evaluation process. The introduction of the assessment and evaluation process begins with the administrative memorandum. In the memo we list the required sections of the design submissions and our general expectations for them. The grading sheets are then developed based on this guidance. Figure 3 shows a portion of the matrix of submission requirements that is included in the administrative memorandum. This matrix gives students a very succinct glimpse into each part of the design submission. If students do not understand the requirements for a portion of the design, this matrix allows a common point of departure for discussion between the student and instructor. Furthermore, it offers a common point of departure for discussion between instructors. Since the grade sheet is developed from this matrix of requirements, all students understand what will be assessed and evaluated from the beginning of the semester. This method is particularly suited for open-ended designs since it is general enough to encourage independent solutions between groups, yet prevents student anguish over ever-changing and multiplying requirements as the design progresses. Additionally, students are given the explanation that suitable coverage of all the listed requirements should lead to a grad of B, while quality and appropriate additions will lead to higher grades.

	Subject	10% Submittal	35% Submittal	100% Submittal
		Introduction		
	USMA Standard Title Page	Required	Required	Required
	A-E Firm's name, logo and project cover page	Required	Required	Required
	Current Executive Summary	Required	Required	Required
		Report Main Body		
I	Project Scope	Feasibility Study	Required	Required
II	Facts Bearing on the Problem	Required	Required (with updates bolded)	Required (with updates)
III	Assumptions Relevant to the Problem	Required	Required (with updates bolded)	Required (with updates)
IV	Needs Analysis	You must describe all the things the structure has to do to function as desired and how it should look.	Update and correct 10% work.	Finalize requirements.
	IV a Functional Requirements	Discuss functional requirements and constraints for the proposed building. This discussion must include floor space, adjacencies, access, parking, etc. Tables are a good technique. Should include deflection and drift limits.	Update and correct 10% work.	Finalize requirements.
	IV b Aesthetic Requirements	Discuss requirements and preliminary designs for internal and external appearances. You may want to break the building down into "functional" parts or areas. Provide plan and elevation views of the facility in an appendix.	Update and correct 10% work.	Finalize requirements.
V	General Approach or Methodology	N/A	Describe the major activities to date and what you did to get to this point. Include your team's task organization—tell who will do what.	Describe the overall methodology used to solve the problem. Tell what you did. Leave the how you did it for the appendices.

Figure 3. Submission Guideline Matrix

Fairly Evaluating Student Work

Perhaps the largest benefit of our grading system is its equitable evaluation of many unique designs. In a typical semester our capstone course will have ten to fifteen design groups of four to five students each. To fairly grade the design and assign grades across the course, the system relies on a criterion component as well as a norm component that compares group efforts and outcomes across the course.

The criterion-based component is implemented by using a grading sheet such as the one in Figure 2. The grading sheet's criteria do not solely consider whether a right or wrong answer is obtained. Not only is there value in producing a correct answer, but perhaps more important is having a correct procedure.[4] Furthermore, calculating a right answer for all designs is typically well beyond the time resources of an evaluator. Therefore, our criteria consider what process was used to determine an answer and the weighting helps compensate for the relative difficulty of that portion of the design. The grading sheet criteria not only evaluate a process but also serve as a checklist for evaluators so that they have a common blueprint to evaluate each unique design. Additionally, the criteria are general enough such that they do not penalize creative thought and unique solutions, but are formalized so that each design gets evaluated equitably.

By coupling a common 10-point scale for equality between sections and design groups with weighting each section based on its relative difficulty and importance, our system ensures the flexibility yet consistency required to fairly grade across numerous designs. Most instructors can easily assess sections using the 1-10 scale to include some using ¼ point increments. Of course deciding on what weight to assign a given section of a submission becomes a very important task. These weights are derived from the unique aspects of the client-based design project, the level of student knowledge and experience, and the instructor's desire for students to explore a particular portion of the design. See the Figure 4 for an example of the criteria used to develop a relative weight.

Example Section Weighting

The lateral load system in the above 10% design submission is worth only 10/200 or 5% of the total grade. This relatively light 5% weight was given to such a major structural system for four primary reasons:

- This is still early in the process and the system is still only at the conceptual stage and not much effort has been devoted to its development
- This is the student's first attempt to lay out their own lateral load system
- The students only have a basic knowledge of how a lateral load system works
- More weight will be given to this portion of the design as the concepts mature and the design of the lateral system is completed.

Figure 4. Weighting Criteria

Once the design submission in divided into components and the relative weights are assigned, the student's submission can be graded. The raw grades (on a scale of 1 to 10) for each section are converted to a percentage and then multiplied by the relative weight of the section and then all sections are totaled for the final submission score.

As well as ensuring equity between assessments for an individual evaluator, the grading sheet also gives a common grading framework that bridge the assessments between instructors. While there is great value in having different evaluators assess a design, we still need to ensure none are over or under compensating a portion of the design based on his or her personal experience or preference (this experience and preference should be applied to developing the design requirements and the grading sheet at the beginning of the process and not first introduced as grading occurs). Finally, all design grades for that portion can be reviewed to assess if the raw scores truly reflect the quality gradient between designs. To help in this overall review, we build a spreadsheet for a side-by-side comparison of all grades by all instructors reviewing the submission. Then we assess whether the points awarded accurately compensate groups appropriately. (See Figure 5 for a portion of the 10% submission spreadsheet). This spreadsheet allows all instructors to see all totals for each section and view how their grading compared to others. And in the final analysis, the spreadsheet allows the course director to assign a final grade based on the criteria in the grade sheet and norm-based comparison across the course.

	Overall Quality		Scope		Facts/Assumpt.		Needs Analysis		A.A.--Site Recon		A.B--Site Plan	
Group	Score	Points	Score	Points	Score	Points	Score	Points	Score	Points	Score	Points
1	6	**6**	9	**4.5**	8	**4**	**7**	**17.5**	**8.5**	**25.5**	**6**	**9**
2	9.5	**9.5**	9	**4.5**	8.5	**4.25**	**8**	**20**	**9.25**	**27.75**	**7.5**	**11.25**
3	8.5	**8.5**	10	**5**	8.5	**4.25**	**8.5**	**21.25**	**8.5**	**25.5**	**5**	**7.5**
4	7	**7**	10	**5**	5	**2.5**	**6.5**	**16.25**	**7**	**21**	**8**	**12**
5	8	**8**	9.25	**4.625**	5.5	**2.75**	**9**	**22.5**	**8.75**	**26.25**	**8**	**12**
6	8.5	**8.5**	8.75	**4.375**	5	**2.5**	**8.5**	**21.25**	**9.25**	**27.75**	**8.5**	**12.75**
7	8.5	**8.5**	9	**4.5**	5	**2.5**	**8**	**20**	**8.5**	**25.5**	**8.5**	**12.75**
8	8.5	**8.5**	7.5	**3.75**	7.5	**3.75**	**8.75**	**21.875**	**10**	**30**	**8.75**	**13.125**
9	10	**10**	10	**5**	8.75	**4.375**	**9.5**	**23.75**	**10**	**30**	**9.5**	**14.25**
10	6	**6**	7	**3.5**	5	**2.5**	**6**	**15**	**6.75**	**20.25**	**5**	**7.5**
11	9.5	**9.5**	10	**5**	8.5	**4.25**	**9.5**	**23.75**	**9.5**	**28.5**	**9.5**	**14.25**
Average		**8.18**		**4.52**		**3.42**		**20.28**		**26.18**		**11.49**

Figure 5. Spreadsheet for 10% Submission Grade Comparison

Clearly Communicating Outcomes

Clearly communicating the outcomes of our assessment and evaluation is the third goal of our system. No doubt many of us have received grades for a major portion of our designs with little more feedback then a letter grade and two to three words of encouragement. Our grading system helps economize the time it takes instructors to give good feedback by grading each section on a scale of one to ten. If a group receives a three on a section, then this section has been deemed to be 30% correct. This number is not lost in the aggregate grade since it is explicitly listed on the grading sheet. Moreover, it is easy for a student to see which sections were particularly strong and which were weak, with minimal discussion from the instructor.

Very often common reasons for particularly poor or strong performance among different sections will be readily apparent to the students. Reasons such as time management, student competencies, and instructor aid can be directly linked as helping or hindering overall performance by assessing commonalities and differences from section to section and how that aspect of design preparation impacted the grade. Additionally, the weighting of each section lets the students know what is particularly important in a given submission and reminds them of the expectations presented at the beginning of the design problem. Finally, discussing student performance becomes much easier even weeks after the submission is returned since the grading sheet serves as a detailed synopsis of the rationale behind the submission's aggregate grade.

Encouraging Follow-up Work

The evaluation of each part of the design leads to the final goal of our grading system - encouraging follow-up and corrective work. A portion of a submission that starts with a low weight will typically increase in importance as the submissions continue during the semester. This way if a group does poor on a section early on, all hope for achieving a good grade is not lost. Instead by explicitly having identified poor performance on a section early in the assessment process, the instructor can encourage students to correct deficiencies before the importance of the section increases and has a significant impact on the final overall grade. In addition, if performance across the course is weak in certain sections of a submission, the instructor can carry forward the requirement to allow students to recapture a portion of the grade that may have been lost in previous submissions as well as focus future class discussions on the section. If the assessment of the design is done only at the completion of the design, or if all scoring is only an aggregate total for a submission, students are unlikely to first understand the source of a poor grade and, therefore, even more unlikely be motivated to correct the problem in a future submission.

Evaluating the Capstone Assessment and Evaluation System

In order to assess the success of our grading system, we first investigated how it impacted our student's perception of the civil engineering capstone experience. The primary metric we use at the United States Military Academy to gauge student perceptions is by analyzing the data gathered at the end of the semester via the USMA course end feedback system. This web-based system asks the cadets a series of questions about each of the courses they have taken at the academy for the current term using a standard five point scale (1 being low and 5 being high). The questions are generated at the academy, civil and mechanical engineering department, civil engineering division and course level and answered by all cadets for all courses they take during the semester. The only major administrative or course content change in the civil engineering capstone course over the last three years has been the implementation of our evaluation and assessment system. The system was fully implemented in 2001 and was unchanged in 2002. Therefore, we used feedback from 2000, 2001, and 2002 to determine the assessment and evaluation system's impact on our student's perceptions of our teaching techniques, communication, and feedback in the civil engineering capstone course. The feedback was also used to compare the capstone course after implementation of the system to all other civil engineering courses. Table 1 contains the summary statistics for the survey questions of interest for every level of response from USMA down to the Civil Engineering Capstone Course.

Data from Academy Course End Surveys

Question	United States Military Academy			Dept. of Civil and Mech. Eng.			Civil Engineering Division			CE Capstone Course		
	Number of Surveys	Ave. Rating	CE Capstone Delta	Number of Surveys	Ave. Rating	CE Capstone Delta	Number of Surveys	Ave. Rating	CE Capstone Delta	Number of Surveys	Ave. Rating	Responses Below 3
Term 2000-2												
A2. This instructor used effective techniques for learning, both in class and for out-of-class assignments.	21239	4.204	0.219	1782	4.445	-0.023	785	4.569	-0.147	45	4.422	3
C7. My instructor communicated effectively.	Not Asked at USMA level			1782	4.592	0.008	785	4.671	-0.071	45	4.600	1
C11. My instructor gave me timely and accurate feedback on my learning progress.	Not Asked at USMA level			1782	4.430	-0.008	785	4.494	-0.072	45	4.422	0
Term 2001-2												
A2. This instructor used effective techniques for learning, both in class and for out-of-class assignments.	20920	4.207	0.471	1711	4.373	0.306	764	4.501	0.177	56	4.679	0
C7. My instructor communicated effectively.	Not Asked at USMA level			1711	4.508	0.402	764	4.597	0.314	56	4.911	0
C11. My instructor gave me timely and accurate feedback on my learning progress.	Not Asked at USMA level			1711	4.488	0.244	764	4.538	0.194	56	4.732	0
Term 2002-2												
A2. This instructor used effective techniques for learning, both in class and for out-of-class assignments.	21433	4.213	0.254	1580	4.354	0.112	711	4.391	0.076	45	4.467	2
C7. My instructor communicated effectively.	Not Asked at USMA level			1580	4.546	0.232	711	4.536	0.242	45	4.778	0
C11. My instructor gave me timely and accurate feedback on my learning progress.	Not Asked at USMA level			1580	4.428	0.194	711	4.416	0.206	45	4.622	0

Table 1. Summary of 2000, 2001, and 2002 Student Survey Results

While it is difficult to conclusively prove a cause-and-effect relationship, the data is highly suggestive that our grading system has had a very positive impact on our students' perceptions of the civil engineering capstone course. Prior to implementing the system (Term 2000-2) the civil engineering capstone course lagged the USMA, Department of Civil and Mechanical Engineering, and Civil Engineering Division averages for using effective teaching techniques, having effective communication, and providing timely and accurate feedback. After the implementation of the system, the civil engineering capstone course responses have outscored the Academy, department, and division in the same three areas.

To further investigate the impact of the assessment and evaluation system, we performed two sets of t-Tests on each of the three questions to see if the differences in means were significant. To test the significance we used a standard risk (or alpha) level of 5%[5] and decided to compare students only in the USMA civil engineering program. We felt this would be a more fair comparison since these students are familiar with our teaching model, and the classes are more similar than if we looked outside the civil engineering division. We compared the mean responses for 2000/2001 (after the change) of the CE division versus the capstone course responses. Subsequently we compared responses for the capstone course in 2000 (before the change) to 2001/2002 (after the change). From the results in Table 2, we found that relative to the civil engineering program the capstone design course had significant and positive differences in all three of the areas impacted by the capstone assessment and evaluation system. Within the course, system implementation significantly and positively impacted the student's perception of our communication as well as timely and accurate feedback. While we would have liked to have seen a positive and significant impact in all three questions within the capstone course, there was no significant change in the student's perception of our teaching techniques. However even this area showed a positive upward trend, albeit not yet significant.

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Question	Difference in Means for Civil Engineering vs. Capstone Design Course Responses in 2001/2002			Difference in Means for Capstone Design Course Responses in 2000 vs 2001/2002		
	Difference in Mean Response	P-Value	Probability that difference is significant	Difference in Mean Response	P-Value	Probablility that difference is significant
A2. This instructor used effective techniques for learning, both in class and for out-of-class assignments.	0.076	3.5%	96.5%	0.044	25.4%	74.6%
C7. My instructor communicated effectively.	0.242	0.000%	100.0%	0.178	3.7%	96.3%
C11. My instructor gave me timely and accurate feedback on my learning progress.	0.206	0.027%	99.97%	0.200	3.4%	96.6%

Table 2. t-Test Results for USMA-wide Course End Survey

Conclusion

Developing a first-class capstone design project does not end when the requirements are passed from instructors to students. Taking full advantage of such an all-encompassing project requires a system that continuously assesses and evaluates the capstone experience as it unfolds. Staff and faculty that assess and evaluate solely based on intuition and personal experience after a final product is completed are missing a wonderful opportunity to teach students who do not share their professional insight or experience nor are they making a strong effort to fulfill ABET criterion 1.

We feel that our capstone evaluation and assessment system does allow our faculty to capitalize on the complete educational benefit of our capstone design. Our system effectively achieves our objectives of clear communication of standards, fair evaluations of very different solutions, clear communication of outcomes, and performance of follow-up/corrective work. Furthermore we feel it is a very important factor in fulfilling the ABET criterion of evaluating, advising and monitoring our students. This system has had a dramatic positive impact on student's perceptions of our ability to communicate effectively as well as give accurate and timely feedback. And perhaps almost as important, its implementation has left no negative perceptions among our students. Also the instructors who use the system find it to be an effective way to ensure consistency in communication and evaluation across designs in a given year as well as year to year. With its flexible and scalable attributes the CE Capstone evaluation and assessment system seems to have helped bridge the gap between student needs and instructor resources while maximizing the educational value of the capstone experience.

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