Peer Evaluation in Senior Engineering Design

Robert T. Bailey[1], Ph.D., Cecelia M. Wigal[1], Ph.D., and Ronald U. Goulet[1], Ph.D., P.E

Abstract

Fair evaluation of student performance and assignment of course grades can be very challenging for the instructor(s) of team-based engineering design courses. Important information about performance can often be obtained from the students themselves. This paper describes a quantitative approach developed at the University of Tennessee at Chattanooga to effectively assess student performance in senior design via written peer evaluations. Tools used to evaluate performance of self, teammates, and team (as a whole) are discussed. Results generated using these tools are also described.

Introduction

In response to the needs of industry and to changing philosophies in engineering education, many engineering programs have extensively revised the design experience included in their curricula. One common theme often forms the backbone of these revisions—ensuring that the students learn to work effectively in interdisciplinary teams. The team-oriented approach leads to a dynamic course environment very different from that of the traditional lecture- and exam-based course. As a result, fair evaluation of student performance and assignment of course grades can be very challenging for the instructor(s) (Thomason and Chopra, 1999).

At the University of Tennessee at Chattanooga (UTC), all senior engineering students take the same two-semester senior engineering design course sequence. The students are divided into teams of six to ten members from various engineering disciplines, with each team tackling a real-world, industrially-sponsored design project.

As instructors, we believe strongly that peer evaluation is an important component of assessing student performance on their projects. This paper describes a quantitative approach developed at UTC over the past two years to effectively assess student performance in senior design via written peer evaluations. The methodology includes assessment of self, teammates, and team (as a whole). Examples of the tools used to perform the assessment are provided so other instructors may use them as a starting point for implementation. Results generated using the assessment methodology are also described and discussed, and strengths and weaknesses of the approach are identified.

Grading Scale

Since the results of the peer evaluations are ultimately translated into numerical scores, it is important to understand the grading scale used in UTC's senior design course. This scale was

---

[1] College of Engineering and Computer Science, University of Tennessee at Chattanooga, 615 McCallie Avenue, Chattanooga, TN 37403

developed as a compromise between a traditional academic scale (*e.g.*, A: 90 - 100, B: 80 - 90, *etc.*) and the more subjective performance evaluation scale that the students are likely to see in industry upon graduation (*e.g.*, poor, adequate, good, superior). The scale is as follows:

5	Strong	-	Exceeds basic requirements in most areas (A work)
4	Good	-	Exceeds basic requirements in many areas (B+ work)
3	Adequate	-	Meets all basic requirements (B work)
1	Unacceptable	-	Fails to meet basic requirements (C-work, at best)

The scale reflects the instructors' belief that at the senior level, B work is required to meet the performance expectations of the course. A score of 2 is occasionally used, as are 0.5 increments, but there is a concerted effort to stick with the four-score scale shown above as much as possible when grading assignments.

Evaluation Tool/Methodology Criteria

The peer evaluation tools/methodology described in this paper were developed to meet three main criteria:

- *Concise but Useful* - The tools should be relatively short, collecting only information that is important to assessing individual and team performance. Experience has shown that too much information can actually be confusing, both to the students and the instructors.

- *Straightforward* - The tools should be easy for the students to complete accurately.

- *Flexible* - The methodology for determining scores based on the information gathered should be flexible enough to allow for instructor input to handle special circumstances (*e.g.*, inclusion of instructor-determined weighting factors or normalization parameters).

Description of Evaluation Tools

Peer evaluation tools were developed in four areas: (1) student evaluation of self, (2) student evaluation of teammates, (3) student evaluation of team, and (4) project manager evaluation of team members. Each of these areas is now described.

Student Evaluation of Self

This portion of the peer evaluation deals with a student's assessment of his or her own performance on the team design project. The tool developed for this purpose is shown in Figure 1. Originally, a far more extensive section was included in which the students were asked to rate themselves on a scale from 1 (poor) to 5 (exceptional) in various performance areas. It was found that this generated very little useful information. Many students appeared unable to honestly critique their own performance using this type of questioning. In addition, each student had a different "internal" scale that was difficult to discern or compensate for when interpreting the results. In contrast, the simple ranking of oneself against one's peers appears to generate very useful information. The students are much more able to honestly assess their overall performance relative to that of the other members of their team in this fashion.

Student Evaluation of Teammates

Using the tool shown in Figure 2, the students are asked to assess the performance of their teammates on the design project. Here, we sought to identify the highest and lowest performers on the team by name, allowing us to assign rewards and penalties where appropriate. By phrasing the first part of the evaluation as "who would you keep" rather than "who would you omit," we found that the students were much more comfortable in completing the evaluation. At one point, we considered asking the students to rate each of their teammates in several performance areas, but the students objected to this approach. They stated that, in many cases, some members of the team had only minimal contact with other members. Thus, they lacked a sound basis for completing a *detailed* performance assessment of many of their peers.

Student Evaluation of Team

The tool shown in Figure 3 was constructed to allow each member of the design team to assess the performance of the team as a whole. The six evaluation areas listed were selected to determine both how well the team was functioning *as a team* and how much progress was actually being made on the project. A linear scale from 1 to 5 was used, as shown in the figure.

Project Manager Evaluation of Team Members

Because they track the activities of the entire team, we believe that the project managers are uniquely able to evaluate each team member in detail. Therefore, the assessment tool shown in Figure 4 was developed to do just that. Each project manager is asked to rate the members of his or her team in seven areas, using a scale from 1 (never) to 5 (always).

Results and Scoring

In this section, typical results obtained from the peer evaluation tools just described are presented, and the methodology used to combine and utilize the information to generate individual and team performance scores is described.

Individual Performance

As a starting point for generating numerical performance scores for each student, the instructors first agree upon an "average student" score that is intended to represent the level of performance of the average student in the class (for example, 3.75). Then, based on the results of the peer evaluations, this score is adjusted up or down as described below.

Student Evaluation of Self. Typical results from the student-evaluation-of-self tool are shown in columns two through four of Table 1. The relative position of each student among his or her peers was assessed by incrementing or decrementing the average student score in proportion to the number of students performing at a level higher or lower than the student in question (see Equation 1 below). The amount of the increment or decrement is determined by weighting factors discussed in the section on Overall Individual Performance which follows.

Student Evaluation of Teammates. Columns five through seven of Table 1 list typical results from the student-evaluation-of-teammates tool. A student's score was adjusted upward each time he or she was included on a peer's "special project" list. Similarly, a student's score was decremented every time he or she was omitted from a peer's "new project" list. Weighting factors were again used to control the size of the increment or decrement (see Equation 1 below for more detail).

Project Manager Evaluation of Team Members. The project manager rated each of their team members in the seven areas shown in Figure 4. Using their responses, an average rating was computed for each member. It was intended that his single score would represent the project manager evaluation component of an individual's peer evaluation score. However, it was found that each project manager treated his or her team somewhat differently when assigning scores, even when the scale was clearly defined (*i.e.*, some were more harsh or lenient than others). To ensure that the class received uniform treatment, it was decided that the project manager evaluation information would be used to discern the spread of individual performance about the "average student" score selected by the instructors. The mean (μ) and standard deviation (σ) of the average scores for the team members were computed, and the standard normal deviate (z) was then calculated for each average score. Based on the value of the deviate, a numerical score between 1 and 5 was assigned according to the scale shown in Table 2.

Overall Individual Performance. The individual performance score (*IPS*) is formed by combining the results of the separate, individually-oriented evaluations as follows:

$$IPS = \frac{\{[B-(w1\times PG)+(w2\times PL)-(w3\times NNP)+(w4\times SP)]+PMA\}}{2} \qquad (1)$$

where *B* = the base student score for the team (set by the instructors; *e.g.*, 3.75)
PG = the number of students that performed greater than the student in question (from student evaluation of self)
PL = the number of students that performed less than the student in question (from student evaluation of self)
NNP = the number of times the student in question was omitted from the new project (from student evaluation of teammates)
SP = the number of times the student in question was included in the special project (from student evaluation of teammates)
PMA = the score from the project manager's assessment of the student in question (from project manager evaluation of team members)
w1 = the weighting factor for *PG* (*e.g.*, 0.2)
w2 = the weighting factor for *PL* (*e.g.*, 0.2)
w3 = the weighting factor for *NNP* (*e.g.*, 0.1)
w4 = the weighting factor for *SP* (*e.g.*, 0.3)

Team Performance

The team performance score was determined by averaging the scores assigned by all team members in the six categories shown in Figure 3. The teams were large enough that normalization of the averages to ensure fair evaluation among team scores was not necessary.

Conclusions

The peer evaluation tools and scoring methodology described in this paper have been successfully applied in the UTC Senior Engineering Design course. They are certainly not perfect and represent a work in progress. Some of their inherent strengths include (1) flexibility in allowing instructor input via weighting factors and the specification of an "average student" score, and (2) simplicity of form design. Potential weaknesses are the lack of detail in some evaluation areas (particularly student evaluation of self) and the requirement for instructor judgment in setting the aforementioned parameters (both a strength and a weakness). It is hoped that instructors at other institutions will find this information helpful when developing or modifying their own assessment tools.

In addition to providing a sound basis for determining the peer evolution component of course grades, the features included in this assessment methodology are also helpful in meeting the requirements of ABET 2000 (Engineering Accreditation Commission, 2000). These criteria call for students to have a demonstrated ability to "function on multidisciplinary teams" and for the institution to have "an assessment process with documented results." Peer evaluations can be an important part of such an assessment process.

References

Thomason, Virgil and Prem Chopra (1999), "Senior Engineering Design: Grading by Objectives," in Proceedings of the 1999 ASEE Southeastern Section Conference, Clemson, South Carolina.

Engineering Accreditation Commission (2000), *Criteria for Accrediting Engineering Programs*, Accreditation Board for Engineering and Technology (ABET), Inc., Baltimore, MD, revised March 18, 2000.

Please provide an assessment of your own performance on your project relative to that of your teammates. Place the appropriate numerals in the three blanks below. Among my project teammates

_____ performed at a level of excellence greater than my own.

_____ performed at a level of excellence equal to my own.

_____ performed at a level of excellence less than my own.

(The total of your three responses should be one less than the number of members in your team. That is, you should account for every person except yourself.)

Figure 1. Student Evaluation of Self Tool

Consider the following scenario: Your team is chosen to participate in a special important project, but there are only enough funds to pay for **all but two** individuals. Based on their performance in this course (and the funding limitation above), whom would you select from your present team to participate in this project? (Include yourself if you believe you should be a team member.)

Name	Why?
1.	
2.	
3.	
4.	
5.	

If one requirement of this project were to send two individuals to the company's national headquarters to join forces with members of other teams to work a highly visible national project, which **two** teammates would you recommend (based on their superior performance on your team)? (Include yourself if you believe you should be one of the representatives.)

Name	Why?
1.	
2.	

Figure 2. Student Evaluation of Teammates Tool

Answer each question set by placing an X at the location on the given linear scale that best describes the performance of the team.

Distribution of Workload
How well was the workload shared among members? Did your PM do the lion's share, or did everyone carry their own weight?

Extremely Unbalanced Very Evenly Distributed
|-----------------|--------------|-----------------|--------------|

Atmosphere of Group Interactions
How well did your group encourage the exchange of ideas? Was the atmosphere conducive to the free exchange of ideas?

Stifling, Belittling, Non-Constructive Open, Supportive
|-----------------|--------------|-----------------|--------------|

Initiative of Group
Within project constraints, how much external direction did your team require? Was the group highly self-directed? Did the group need external input on every decision? Did the group respond in a timely manner to sponsor requests with minimal oversight?

High Maintenance, Never the Initiator Fully Self-Directed, Completely Self-Reliant
|-----------------|--------------|-----------------|--------------|

Amount of Work Accomplished
How much work did your team actually accomplish? Did you set aggressive goals and objectives and exceed them all, or did you set un-ambitious goals and objectives and fail to meet even those?

Very Little Progress Exceptional Progress
|-----------------|--------------|-----------------|--------------|

Quality of Work Performed
How much pride and satisfaction do you take in the accomplishments of your team? Would you hold up your team's work products in a job interview to show excellence?

Embarrassed (very poor quality) Proud (exceptional quality)
|-----------------|--------------|-----------------|--------------|

MVT or MDT?
Which award would your team have the best chance of winning: MVT (Most Valuable Team) or MDT (Most Dysfunctional Team)?

Most Dysfunctional Most Valuable
|-----------------|--------------|-----------------|--------------|

Figure 3. Student Evaluation of Team Tool

For each of the statements below, rate each team member on a scale of 1 to 5, where 1 indicates "*Never*" and 5 indicates "*Always without exception.*" Respond based on your experience as Project Manager. Do not rate yourself.

	TEAM MEMBERS							
	1	2	3	4	5	6	7	8
Attended team meetings and activities.								
Showed up for team meetings and activities promptly.								
Showed up for team meetings and activities fully prepared.								
Completed assigned tasks fully and on time.								
Submitted very best quality work.								
Contributed above and beyond in team discussions.								
Contributed above and beyond in work related to team presentations and/or reports.								

Figure 4. Project Manager Evaluation of Team Members Tool

Table 1. Results from Student Evaluation of Self, Student Evaluation of Teammates, and Project Manager Evaluation of Team Members Tools

Name	Student Evaluation of Self – Performance Comparison			Student Evaluation of Teammates – New/Special Project Lists			PM Evaluation of Team Members		Student Peer Evaluation Combined Score
	Performed Greater	Performed Equal	Performed Less	On New Project	Omitted from New Project	On Special Project	Average over 7 categories	Adjusted based on z	
Member 1	1	2	2	3	3	1	3.43	2.75	2.87
Member 2	0	2	3	6	0	6	4.43	4.50	4.62
Member 3	0	1	4	6	0	5	4.43	4.50	4.74
Member 4	2	2	1	4	2	0	4.14	4.00	3.48
Member 5	2	3	0	3	3	0	3.57	2.75	2.60
Member 6	2	1	2	2	4	0	3.71	3.25	2.90

Table 2. Assignment of Scores for Project Manager Evaluation of Team Members

Range of z	Score Assigned
$z > 1.2$	5.00
$1.25 = z < 0.75$	4.50
$0.75 = z < 0.33$	4.00
$0.33 = z < -0.33$	3.75
$-0.33 = z < -0.75$	3.25
$-0.75 = z < -1.25$	2.75
$-1.2 = z < -1.75$	2.00
$z = -1.75$	1.00

Robert T. Bailey

Dr. Bailey is an assistant professor of engineering at the University of Tennessee at Chattanooga (UTC). He received his B.S., M.S., and Ph.D. degrees in mechanical engineering from University of Florida, the latter in 1991. Before coming to UTC in 1999, he worked in industry for over 8 years, serving as a Senior Program Officer for the National Research Council, as a Senior Engineer and Branch Manager for Science Applications International Corporation (SAIC), and as a Senior Engineer with Westinghouse Savannah River Company. His primary areas of interest and expertise include thermal/fluid system analysis (predicting behavior under off-normal, transient conditions), quantitative risk assessment (QRA) and safety enhancement of engineered systems and industrial processes, computational fluid dynamics (CFD), and application of computer technology to engineering education.

Cecelia M. Wigal

Dr. Wigal is an assistant professor of engineering at the University of Tennessee at Chattanooga (UTC). She received her B.S. degree (electrical engineering) from Ohio Northern University (1985), her M.S. degree (electrical engineering) from Illinois Institute of Technology (1991), and her Ph.D. degree (industrial engineering and management science) from Northwestern University (1998). Before coming to UTC in 1999 and before undertaking her Ph.D. work in 1993, she worked in industry for over 8 years as a Project Engineer and Senior Project Engineer in the Aerospace Electrical Systems Division of Sundstrand Corporation (now Hamilton-Sundstrand). Dr. Wigal's primary areas of interest and expertise include complex process and system analysis (ensuring representativeness while minimizing bias and data overload), quality process analysis with respect to fast-paced growth, and information system analysis with respect to usability and effectivity.

Ronald U. Goulet

Dr. Goulet is an assistant professor of mechanical engineering at the University of Tennessee at Chattanooga (UTC). He received his B.S. in civil engineering from Northwestern University (1976) and his Ph.D. in Engineering (in the field of fracture mechanics) from the University of New Hampshire (1997). He joined the UTC engineering faculty in 1998 with over 20 years of professional experience serving the power, legal and insurance industries in Chicago and Pittsburgh. Dr. Goulet's primary research interest includes the application of 3D vision based displacement measurement techniques in experimental mechanics. As director of UTC Biomechanics lab, Dr. Goulet coordinates experimental research of implanted orthopedic constructs in collaboration with the Dept. of Orthopedic Surgery, Chattanooga unit of the UT College of Medicine.