Int. J. Engng Ed. Vol. 23, No. 4, pp. 698–704, 2007
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Peer Evaluation as a Motivator for Improved Team Performance in Bio/Ag Engineering Design Classes*

[1]BARBARA C. WILLIAMS, B. BRIAN HE, [2]DONALD F. ELGER and [3]BRIAR E. SCHUMACHER
[1] *Biological and Agricultural Engineering, University of Idaho, Moscow, ID, 83844, USA.*
E-mail: barbwill@uidaho.edu
[2] *Mechanical Engineering, University of Idaho, Moscow, ID 83844, USA. E-mail: delger@uidaho.edu*
[3] *Cedric D. O. Chong and Associates, Honolulu, Hawaii, HI 96813, USA.*

At the present time it is common practice to begin teaching teamwork skills to first year students. Teamwork skills have been identified by industry and the Accreditation Board for Engineering and Technology (ABET) as critical to engineering success in the workplace. There are many factors that are associated with learning effective team performance. In this study, we are interested in a simple question—does peer evaluation influence team performance and if so, how? To answer this question, we used qualitative and semi-quantitative questions in individual surveys of Bio/Ag students who have completed our first year student and sophomore design courses where (a) in the first year team performance was not directly assessed, and (b) in the second year team performance was evaluated by peers and professor, and the evaluation was part of the design project grade. The major finding of the study was: while students connected logically with the idea of peer evaluation at the end of a project, they report that this evaluation did not influence their performance. However, the students welcomed structured peer feedback during the project. Together, this finding suggests that professors should structure peer-feedback during a project, with peer-evaluation at the end of the project.

Keywords: teamwork; peer evaluation; open ended survey; ABET

TEAMWORK

THE CONCEPT IS EMPHASIZED in the engineering curriculum at the University of Idaho and across the nation. In the Biological and Agricultural Engineering Department at this university, teaming is specifically targeted for first year student, sophomore and senior capstone design courses. The value of good teaming skills for successful performance of engineers has been identified by industry as reflected by the Accreditation Board for Engineering and Technology (ABET) criteria #3d. 'an ability to function on multidisciplinary teams' [1]. Because of the present explosion in biotechnology, biological and agricultural engineering graduates will be called upon increasingly to work in interdisciplinary teams. Emerging pedagogical approaches, such as cooperative learning and peer assessment/evaluation are especially well suited to engineering design courses, because design requires inductive reasoning, where there is potentially more than one solution to a problem. A functional team can generate, refine and evaluate more design alternatives than one person. The value of collaborative learning [2, 3], and teamwork [4, 5, 6], have been documented extensively. 'A team is a small number of people with complementary skills who are committed to a common purpose, performance goals and approach for which they are mutually accountable' [6]. Successful teamwork has been said to include many elements, two of which are peer assessment and peer evaluation [4]. In this paper, the term 'assessment' is defined as feedback provided for improvement; 'evaluation' is defined as a judgment of quality as measured against some standard, as when determining a grade [7]. Accepting the premise that good teamwork skills are fundamentally necessary for improving engineering student learning and performance, the follow-up question is 'does peer evaluation influence team performance and if so, how?'

We encountered an opportunity to investigate student perceptions of teammate participation and accountability within our own curriculum because of a difference between our first year student and sophomore classes. The teamwork structure for the design projects of these two courses differed in several aspects, but in particular:

(a) in the first student year, team performance (process and function) was not directly assessed;
(b) in the second year team performance was evaluated by peers and professor, and the evaluation was part of the design project grade.

* Accepted 17 June 2007.

In the first year student course, Myers Briggs Type Indicators (MBTI) are introduced, and students are typed according to MBTI. This is done to demystify and defuse some of the classic synergies/conflicts that can result from various pairings of types [8]. Teams of two people carry out design projects, and assessment occurs as follows:

(a) students assess the team process in terms of the MBTI categories twice in the semester;
(b) professor provides verbal assessment of process and evolving content (designed artefact) over the course of the semester;
(c) professor assigns team grade.

To date, students have been provided with a grading rubric for the designed product, but have not been provided specific performance criteria for teamwork skills, e.g. team goal setting, performing within a role, conversing, debating, group decision making, etc. [9].

In the sophomore course, teams of three to four people complete semester-long course projects. Each team chooses its own leader by a consensual or democratic process. The team leader's performance is measured against the following checklist:

(a) organize and coordinate group 'research' activities among members and between the group and the instructor;
(b) ensure that team deadlines are met;
(c) lead the team in report writing and presentation;
(d) lead team discussions on any issues.

The professor provides a significant assessment (feedback, not evaluation) of each team product for a mid-project outline/progress report. Team leaders are invited to bring problems to the attention of the professor during the semester. At the beginning of the project students are provided with the specific rubrics the professor will use for evaluation of the written product and the final presentation. They are also provided a rubric for self/peer evaluation of their teamwork participation, accountability and leadership during the semester (Table 1).

Note that the quality of 'leadership' for each student depends upon leadership (proactive integration into team function) with respect to assigned role. Assigned roles vary, but may include biological scientist/engineer, process engineer, design engineer, engineering economist or marketing engineer in addition to team leader. Therefore, the marketing engineer would be assessed for the

Table 1. Self/peer evaluation rubric for team participation. Students are asked to evaluate themselves and peers

BAE242 Course Project
Peer Evaluation Form
(Due on Presentation day)

Presenting Team:_____

Instruction: Evaluate your peer team members, including yourself, on their participation in the course project. Circle the appropriate rating for each criterion.

			Rating		
	Team Member Name	Activities	Average	Good	Excellent
1		• Participation in the project activities • Fulfilment of his/her role duties • Leadership Overall	3 3 3 3 3.5	4 4 4 4	5 5 5 4.5 5
2		• Participation in the project activities • Fulfilment of his/her role duties • Leadership Overall	3 3 3 3 3.5	4 4 4 4	5 5 5 4.5 5
3		• Participation in the project activities • Fulfilment of his/her role duties • Leadership Overall	3 3 3 3 3.5	4 4 4 4	5 5 5 4.5 5
4		• Participation in the project activities • Fulfilment of his/her role duties • Leadership Overall	3 3 3 3 3.5	4 4 4 4	5 5 5 4.5 5
General Comments					

leadership s/he took for the quality and integration of the marketing effort as part of the overall team effort.

The peer evaluation data (see Table 1 above) in the sophomore course are used in the following manner. The total weight for the written semester project is 10% of the semester grade. The professor grades the written project, and individuals rate themselves and each other according to Table 1. If the average score for Student A is 5 as rated by his/her peers and him/herself, then that student receives 100% of the professor's score. If the average score for Student B is 4.5 peer-rated, he/she receives 90% of the professor's grade for the design project. Therefore, the peer evaluation can have significant impact on the student's grade for the project, but can impact no more than 10% of the semester grade. As stated above, this grading rubric is given to the students at the beginning of the project.

The professor of the sophomore course selected this peer evaluation technique because he concluded that team-mates were in a better position than he to conclude whether each team member participated, fulfilled his/her roles and demonstrated leadership. He clearly articulated this reasoning to the students when introducing the grading rubric.

Objective

The objective of this study was to determine whether the spectre of peer evaluation provides a greater motivation for overall performance than if no peer evaluation is planned. To determine this we asked the students to compare how they felt during their sophomore design project as compared to their first year design project. The first year student course identifier is BAE 142, and for the sophomore course it is BAE 242.

Method

A survey was written to address the general question 'does peer evaluation influence team performance and if so, how?' Open-ended questions for which students could provide their own answers (described below), were followed by leading questions for which students could numerically scale their response (Table 2). The open-ended questions were provided on the first page of the survey, and students were instructed to complete this before starting the next page. By doing this we sought to solicit self-generated (uninfluenced) answers first. Page 2 of the survey included questions with a numerical scale so that we could separate factors that we considered to be relevant to the topic of motivation for improved performance.

Results

Completed surveys were collected from 18 students, most of them seniors. The first open-ended question, and responses to it, can be found in Table 3. When asked whether 'knowing you would be graded by your team-mates as well as your professor changed your behaviour or attitude toward working on a team', not a single student said 'yes'.

This was consistent with the trend of responses

Table 2. Numerically scaled questions in the survey. Questions were posed with the following introduction: For the questions in the following table, think back, and compare how you felt in BAE 242 as compared to BAE 142, knowing that your peers would grade you in 242

How much do you agree with the following statements?	Strongly Disagree (Circle one number)				Strongly Agree
1. When we graded team-mates I worked harder	1	2	3	4	5
2. When we graded each other my team-mates worked harder	1	2	3	4	5
3. When my team-mates graded me I tried harder to attend all meetings than I would have otherwise	1	2	3	4	5
4. When we graded team-mates we were more professional	1	2	3	4	5
5. When we graded team-mates, it improved communication—i.e. everyone's opinion was heard	1	2	3	4	5
6. When we graded each other, I worked harder to make sure I pulled my weight	1	2	3	4	5
7. When we graded each other, I tried harder to get my team-mates to pull their weight	1	2	3	4	5
8. When we graded each other, I think the overall quality of the design improved	1	2	3	4	5
9. *In your future career you will work on teams with people from other disciplines (e.g. soil microbiologists, politicians, medical doctors, farmers, or marketing experts).* Do you think the experience of being graded by your peers has improved your ability to work on interdisciplinary teams in the future?	1	2	3	4	5
10. When I graded my teammates, I was fair	1	2	3	4	5
11. When I graded my peers, I was reluctant to grade them too harshly, so I might have graded too easily	1	2	3	4	5
12. When I graded at the end of the process, I figured we were done, so why bother being critical of people now	1	2	3	4	5
13. We should have done midterm peer grades so we could let the prof know if someone wasn't contributing	1	2	3	4	5

Table 3. Responses to the question: Think back, and compare how you felt in 242 as compared to 142.

Question	Y	N	Didn't answer, or provided non-rejoinder answer
Did knowing you would be graded by your team-mates as well as your professor change your behaviour or attitude toward working on a team?	0	15	3

to the numerically scaled responses (Table 4) for different aspects of being graded.

For questions 1, 2, 3, 4, 5, 6, 7, and 8, the average response was always on the slightly 'no' side of neutral. That is, the majority of the students felt that being graded did not significantly impact on their behaviour or that of their peers. The largest number of students reported agreement or strong agreement (seven 4's and one 5) for question 8 of Table 4, which states that 'when we graded each other, I think the overall quality of the design improved'. However, the average (2.9) for that question is still neutral.

Table 5 indicates that students did identify advantages to having peer evaluations—9 individual pros were provided from among the 18 students, as compared to 8 individual cons.

Similarly, in Table 6, students identified positive effects on their own team's performance in seven separate instances. Note in Table 5 that the pro most frequently cited was the one posed by the professor at the beginning of the course, suggesting that the students trusted him and 'bought in' to his grading schema.

The students were also neutral about whether being graded could potentially improve their ability to work well on interdisciplinary teams. It may be important to note that in both classes the teams self-sorted when forming the teams. Students in our programme have (until 2004) been required to declare their major as either Ag Engineering or BioSystems Engineering. All teams in these classes were populated either 100% with one or the other.

A majority of students assessed themselves as fair (i.e. equitable) when they graded their team-mates (see Table 4 above). A majority of students also said that there should be mid-project peer grades, so the professor would be alerted if someone was not contributing. This appears to be an important message, especially in view of the fact that both professors had verbally invited students to seek his/her counsel if problems developed within a team. This answer implies that students invite a formalized process check, which relieves them of having to decide whether an intervention is called for.

The negative perceptions articulated by students included the potential for unfair, biased or 'uptight' grading on the part of their peers, interesting when juxtaposed with the strong feeling that they themselves were fair graders. Social concerns about 'turning in' a peer were also voiced.

IMPLICATIONS OF SURVEY RESULTS

Students were able to suggest potential or realized pros and cons (see Tables 5 and 6 above)

Table 4. Statistics for responses to numerically scaled questions in the survey

How much do you agree with the following statements?	Avg. (n=18)	Std. Dev.
	Strongly disagree = 1 Strongly agree = 5	
1. When we graded team-mates I worked harder	2.3	1.1
2. When we graded each other my team-mates worked harder	2.7	1.0
3. When my teammates graded me I tried harder to attend all meetings than I would have otherwise	2.2	1.1
4. When we graded team-mates we were more professional	2.6	1.0
5. When we graded team-mates, it improved communication—i.e. everyone's opinion was heard	2.8	1.2
6. When we graded each other, I worked harder to make sure I pulled my weight	2.8	1.1
7. When we graded each other, I tried harder to get my team-mates to pull their weight	2.7	1.2
8. When we graded each other, I think the overall quality of the design improved	2.9	1.3
9. *In your future career you will work on teams with people from other disciplines (e.g. soil microbiologists, politicians, medical doctors, farmers, or marketing experts).* Do you think the experience of being graded by your peers has improved your ability to work on interdisciplinary teams in the future?	2.9	1.3
10. When I graded my team-mates, I was fair	4.2	1.1
11. When I graded my peers, I was reluctant to grade them too harshly, so I might have graded too easily	2.8	1.5
12. When I graded at the end of the process, I figured we were done, so why bother being critical of people now	2.3	1.4
13. We should have done midterm peer grades so we could let the prof know if someone wasn't contributing	4.1	1.2

Table 5. Responses to open-ended question: What do you feel are the pros and cons of grading your teammates and being graded by them?

Pros	Cons
Teammates are better informed as to your performance, any grade they give is probably more accurate than that of the prof (3 versions of this idea)	Personal disputes can cause biased grading, (4 versions of this idea)
Might inspire people to pull their weight more, (2 versions of this idea)	I don't think it is accurate—I never judged harshly enough
Ability to hold team members accountable, (2 versions of this idea)	If you have a member that is "uptight", then you are judged by their standards
OK as long as team grade is only part of teamwork grade	I come from a society where students are considered "brother" so it is hard for me to hurt other students
Evaluated by work ethic	I wanted to give a student a low grade but was afraid he would know it was me because our team was small

Table 6: Response to open-ended question: How did team grading affect the team dynamic?

Positive effect on team performance	Neutral Tone	Negative effect on team performance
This made each team member put more effort toward project, because they knew that the team was grading them (4 versions of this idea)	It was the same as it would have been if we didn't grade each other (6 versions of this idea)	It was uncomfortable—I wanted to give my team member a low grade but was afraid he would know it was me because our team was small
More communication among team members	I don't remember	Some resentment
More concern in making sure everyone got along	I couldn't tell	
The team I worked with was positively affected by these grading techniques		

for being graded by peers on team performance. The pros they identified suggest that they believe peer evaluation can be potentially motivating. However, in Tables 3 and 4 the students reported that knowing they would be graded by their teammates in addition to their professor did not have a significant effect on their behaviour or attitude toward working on the team. The effect reported was neutral, neither negative nor positive. To summarize, they were able to articulate an intellectual justification for peer grading, but not report a personal motivation.

An important conclusion we can take from this study is that the majority of students felt that a mid-project process check of individual members' performance of pre-assigned responsibilities would be an advantage. If a semester-end evaluation is not a motivation, then perhaps ongoing assessment can be. This is consistent with a summary of the education literature provided by Stiggins [10] on the subject of motivation. He posits that in order to motivate, we must:

- be crystal clear about the achievement targets we want the students to hit;
- perform high quality assessments of relevant skills for the task at hand so we can determine if the students are succeeding;
- identify/communicate when successes occur and communicate suggestions for improvements so that the students can take ownership for their improvement.

On the basis of these survey results, it appears that professors of classes with important team design components should

(a) select certain cognitive and social skills necessary for engineering design teamwork [9];
(b) define performance criteria (with the involvement of the students to increase student ownership) for successfully demonstrating those skills;
(c) assess, and have students self-assess, the improvement of team skills and product quality over the course of the project lifetime.

CONCLUSIONS AND DISCUSSION

Students having experienced the peer grading approach described above can articulate logical explanations for its being valuable, but do not perceive it to be strongly motivating or to have strongly influenced their behaviour. A majority of them identified ongoing feedback about team function to be worthy of incorporation in teamwork design projects.

It is important to emphasize that peer evaluation

in this case had the potential impact on only 10% of the student's grade of the semester. It is possible that the motivations described by the students might be different in the case of higher stakes—for example, if the peer evaluations impacted 20% or more of the grade.

Acknowledgements —The authors would like to thank all the students who willingly responded to the survey during their busy semester. This work was funded in part by the National Science Foundation: Grant Numbers EEC0212293 and DUE-0088591. This work was also funded in part by the University of Idaho Department of Biological and Agricultural Engineering, Department of Mechanical Engineering, College of Engineering, Research Office and Office of the President.

REFERENCES

1. Accreditation Board for Engineering and Technology (ABET), 2004–2005 *Criteria for Accrediting Engineering Programs, p. 2*. ABET, Inc., Baltimore, MD (2003). <http://www.abet.org/criteria.html>
2. National Research Council, *Cooperative Learning—Learning, Remembering, Believing*, Chapter 5. National Academy of Sciences, Washington, DC (1995).
3. M. C. Hersam, M. Luna and G. Light, Implementation of Interdisciplinary Group Learning and Peer Assessment in a Nanotechnology Engineering Course. *J. Engr. Educ*. **93**, 2004, pp. 49–57.
4. S. D. Carr, E. D. Herman, S. Z. Keldsen, J. G. Miller and P. A. Wakefield. *The team learning assistant workbook*. McGraw Hill, New York (2005).
5. F. LaFasto and C. Larson. *When teams work best: 6000 team members and leaders tell what it takes to succeed.* Sage, Thousand Oaks, California (2001).
6. J. R. Katzenbach, and D. K. Smith. *The wisdom of teams: creating the high-performance organization*. Harvard Business School, Boston (1993).
7. M. Baehr, Distinctions between Assessment and Evaluation, in *Faculty Guidebook, a Comprehensive Tool for Improving Faculty Performance*. Pacific Crest, Inc., Lisle, IL (2004).
8. S. K. Hirsch, *Introduction to Type and Team*, Consulting Psychologists Press Inc., Palo Alto (1992).
9. M. Baehr, S. Beyerlein, W. Duncan-Hewitt and Bobbie Klopp, *A Classification of Learning Skillls for Educational Enrichment and Assessment*, Pacific Crest, Inc., Lisle, IL (1997).
10. R. J. Stiggins, *Student-Involved Classroom Assessment*, 3rd Ed. Merrill/Prentice Hall, Upper Saddle River, NJ (2001).

Barbara C. Williams is an assistant professor in the Department of Biological and Agricultural Engineering at the University of Idaho. She has practiced water resources and environmental engineering for 22 years. Her research is focused on groundwater contamination, groundwater transport of colloids and engineering education. She teaches fluid mechanics, water treatment processes, advanced fluid mechanics of porous media, and an introductory engineering design course. She earned a BS in Engineering at Swarthmore College, an MS in Civil and Environmental Engineering at Cornell University and her doctorate in Agricultural Engineering at the University of Idaho.

B. Brian He is a bioprocessing engineer and assistant professor in the Department of Biological and Agricultural Engineering at the University of Idaho. He obtained his BS and MS degrees in Chemical Engineering from Tianjin University, and his doctorate in Agricultural Engineering from the University of Illinois at Urbana-Champaign. He also holds an MS degree in Biosystems Engineering from University of Hawaii (1996). His research interests are in the areas of biological/ biochemical/ chemical processes for biofuels and value-added industrial products from bio-based resources. He teaches in the areas of transport processes in biological systems, food and bio-based process engineering, engineering analysis and design, and agricultural process engineering. He is an associate editor for the *Transactions of the American Society of Agricultural Engineers* and *Applied Engineering in Agriculture*.

Donald F. Elger has been a Professor in Mechanical Engineering at the University of Idaho for 18 years; his technical interests are heat transfer, fluid mechanics, and design. He received his BS in Nuclear Engineering from Oregon State University, and his MS and doctorate degrees in Mechanical Engineering from Oregon State University. His educational research interests are in qualitative and mixed methods involving mentoring, instructional design, science of learning and organizational change via the creation of communities of practice.

Briar E. Schumacher is a practicing engineer employed by Cedric D. O. Chong and Associates in Honolulu, Hawaii. Her technical interests are product design and social research emphasizing grounded theory methodology. She graduated in December 2003 with a degree in Mechanical Engineering from the University of Idaho. She contributed significantly to the design of the survey presented in this paper.