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## **AC 2011-533: INCORPORATING TECHNICAL PEER REVIEW OF CIVIL ENGINEERING STUDENT PROJECTS**

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# Incorporating Technical Peer Review of Civil Engineering Student Projects

## Abstract

Practicing engineers use peer review of most work products on a regular basis. While peer review of team members and peer review of classmate's writing and presentation has been extensively researched, the use of student peer review of engineering work products has not been similarly explored in engineering. This paper presents the implementation of a peer-review cycle into the team course project in both a junior-level structural analysis course and a senior-level capstone civil engineering design course. The peer review process asks students to evaluate and provide feedback on both the analytical content as well as the written presentation of the project. This process allows students to see different approaches to the same problem. Their familiarity with the problem allows them to provide constructive feedback, while reviewing the work of another group allows them an objectivity they cannot yet apply to their own work. The peer review cycle not only enhances the learning of the material for the course, but it is also a critical engineering skill for students. This paper presents a model for classroom practice, which is based on the peer review, tutoring, and teaching literature, to develop both knowledge and skills in students.

## Introduction

Active and project-based learning (PBL) strategies provide a great means for students to enhance their learning and further develop critical engineering skills [1-6]. PBL provides complex tasks based on challenging questions or problems that involve the students' problem solving, decision making, investigative skills, and reflection. The activities are student centered and focus on real-world problems and issues, which further helps motivate students to learn. However, students still struggle with making decisions between approaches and when not given exact procedural steps want the reassurance they are "doing the correct thing" to meet the project requirements [2, 7]. Higher-order thinking by students involves the transformation of information and ideas. This transformation occurs when students combine facts and ideas and synthesize, generalize, explain, hypothesize or arrive at some conclusion or interpretation. These skills are valued because they better prepare students for the challenges of professional practice and daily life, as well as for advanced academic work. Bloom's revised taxonomy is a multi-tiered classification system for learning that identifies six cognitive process categories in increasing complexity [8-9]. Research indicates that PBL can frequently and reliably get students to reach the Applying level [10], student's struggle with the Analyzing and Evaluating levels, and frequently do not reach the Creating level of the taxonomy.

In order to address these issues, a technical peer review cycle was introduced into the project component of several junior and senior level courses. The goal of peer review is to improve student's higher-order thinking skills, specifically critical thinking and metacognitive skills, through learning how to perform peer review of civil engineering products. Approximately half-way through the project completion, student teams are asked to review the work being done by another student group and provide formative assessment that can be used to refine and improve the work in progress. This approach is grounded in existing educational research into *how people learn* [11], as well as the benefits of *peer review* on developing student writing abilities [12-13].

In this case, development of content knowledge is targeted in addition to increasing students' communication ability. The model follows a direct teach, then learn by doing, and finally, a learn by reviewing/teaching format.

The outcomes of this process include:

- **enhanced motivation:** to improve the quality of both the learning process and the ability to give (and receive) constructive feedback;
- **improved cognition and social outcomes in learning:** to encourage deeper level or higher-order thinking, and to develop collaborative skills;
- **an increased sense of responsibility for one's own learning:** to enhance ownership of the learning process and the constructed knowledge; and
- **improved metacognitive skills:** to enable students to reflect more critically on their learning.

In summary, this paper presents a model for classroom practice, which is based on the peer review, tutoring, and teaching literature, to develop both knowledge and skills in students. Evidence of the effectiveness of this strategy is presented, including comparing student performance when peer review is utilized with the performance without peer review.

## Course and Project Descriptions

### CVEN 345 – Theory of Structures

Structural analysis, or Theory of Structures, is part of a strict course sequence within the civil engineering degree plan. The sequence starts with basic Statics, which can only be taken after the completion of the freshman year. The sequence then progresses into Mechanics of Materials, into Structural Analysis, and finally to at least one senior structural design course, which may be steel or concrete design. All civil engineering students are required to take the above course sequence, independent of their area of specialization. Only 15-20% of all students choose to specialize in structural engineering, the most directly relevant specialty area to the sequence.

A “typical” syllabus for a structural analysis course might include the following topic list:

1. Analysis of determinate beams and frames: determinacy; reactions, shear, and moment diagrams;
2. Analysis of trusses: classification; method of sections; method of joints;
3. Influence lines for determinate structures: trusses; beams; vertical loads on frames; moving loads;
4. Approximate indeterminate analysis: portal method; cantilever method; moment diagram from deflected shapes;
5. Deflections: double integration; moment-area; conjugate beam; virtual work; virtual work for trusses; virtual work for beams; virtual work for frames; theorems of Maxwell, Betti and Castigliano; and
6. Indeterminate analysis: superposition; influence lines for indeterminate beams, frames and trusses; slope-deflection equation; moment distribution without side sway; moment distribution with side sway; introduction to matrix structural analysis.

Other topics such as approximate methods, column analogy, cables, arches, curved beams, etc. often are added at the discretion of the instructor

Project-enhanced learning is not typically part of the traditional course structure. However, since Spring 2004 some of the course instructors have chosen to incorporate this learning experience into the course [7]. Much like problem-based learning [8-10], the students are given a realistic problem with the goal to aid the students in the acquisition of critical knowledge, problem solving skills, self-directed learning and teamwork. Projects can be particularly effective metacognitive experiences as they require several skills that are metacognitive in nature: planning the way to approach a learning task, monitoring comprehension, and evaluating the progress towards the completion of a task.

The projects for the structural analysis course have several objectives: 1) to allow students to tackle a larger and more realistic civil engineering problem; 2) to expose students to computational tools used in solving civil engineering problems; and 3) to evaluate critical thinking and communication skills. The projects are designed to be solved by student teams, who are told they are acting as consultants on the project posed. The project increases in complexity as the semester progresses, where initially the number of choices and variations available are few, and progress to an open-ended solution being required of the student teams. The projects are designed to emphasize interpretation of numerical results rather than pure numerical computations. The content objectives of the course are the focus of the project, but they also require a connection between previous knowledge to new concepts, and connecting new knowledge to concepts in other courses and/or disciplines.

Positive results from implementing projects have been documented [7] and clearly demonstrate that the students perceive benefits from the projects in their analysis course. These benefits include specific skills related to ABET outcomes (such as problem solving and teamwork) as well as benefits in motivating, learning, and understanding the course content. The students perceive these benefits while still struggling with the course requirements, and the perception continues in later courses where they also see an impact in improved performance when compared with students not exposed to the projects. However, students still struggle with evaluating the choices and assumptions made as well as with how to analyze and interpret their results when not given a specific solution presentation or process. For example, the project asks that internal forces and stresses be determined for the structure, but it does not specify how those results are to be presented. Students then ask for specific instructions: “Do you want a table? Graphs? How many? They are not comfortable when the instructor replies asking them to consider why those results are important in the context of the entire project and to use that to determine how to best present the information.

#### CVEN 400 – Capstone

This study was conducted in a senior capstone design class for civil engineering students. Self selected groups of four or five students work in a largely self directed environment to design a project. The project for the semester reported herein was to create a design for a neo-traditional neighborhood on a 46 acre tract of land about 10 miles south of the campus. In addition to the

on-site design issues to meet client expectations; students are required to grapple with a range of other issues typical to this type of engineering project:

- city design standards and development ordinances;
- environmental impacts (the tract includes floodplain);
- impacts to adjacent property owners (primarily stormwater); and
- property access issues (although the track is bounded on two sides by streets, neither is currently sufficient to serve the development).

The student teams were provided with a site survey and topographic map of the site and immediate surrounding area.

### **Implementation of Student Peer Review**

In order to address the issues identified above, a peer review cycle is introduced into the project course component. A peer-review of the performance of the team members was already utilized in prior implementations of the project. In a cooperative learning environment, students themselves are often in the best position to provide one another with meaningful feedback regarding both their technical and interpersonal performance [11-12].

The peer-reviews are double blind: the students don't know who they are reviewing, nor do they know who reviews their work. Additionally, the reviews rotate among the groups for the two different project parts, maximizing the diversity of feedback a group can receive as well as exposing students to a greater variety of approaches. Additionally, the peer-review is utilized in a strictly formative fashion, and score peers give to another group are not included in the final grade computation. Rather students groups are graded on the quality of the peer-review feedback provided. So peers have no incentive to grade harshly (skew the "curve") or to grade easily (benefit their "friends").

The instructions for review given to the peer groups include the rationale for doing the review and are given below:

"Part of your team's responsibility will be to review the work submitted by another team in your class. Reviewing the work of another engineer with a critical eye is an important skill that you will use frequently in your professional career. The goal is to provide constructive feedback so that future work submitted by the team is improved. Your team will be evaluated on the quality of the feedback provided – being too easy or too hard will not help anyone improve as well as instructions on marking projects and grading rubrics."

It is critical to emphasize what students are learning in terms of course content, as well as what they are gaining in other ways from performing the peer-review cycle. Both parts of the peer review cycle add to the learning outcomes (learning from the good and bad approaches attempted by the other team & getting peer feedback about the clarity and correctness of their own approach). This not only improves student motivation and the quality of the work, but it also increases the desired outcomes from the activity. Other ABET outcomes, such as professionalism, communication, etc. also benefit from the peer review activity.

Specific rubrics are provided for students to evaluate both the written report (30% of project grade) as well as the analytical content (70% of project grade) of the project. The rubrics breakdown those two components into the following categories:

- Report: organization, writing, content
- Analysis: organization, content

Within each sub-component, additional elements are listed to guide the students into what they should be evaluating. For example, under the Report Organization section, the following sub-categories are identified:

- The heading of a memo complete: includes all components (such as To, From, Subject and initials)
- All sections present and in correct order
- Figures and tables numbered sequentially and with captions
- Figures, tables referred to in text
- Figures with multiple curves have legends
- Calculations and codes in appendix

In contrast, the Report Content section has sub-elements focusing on the specific report components (such as Introduction, Problem Description, Results, etc...) and specific criteria for each element. For example, the Results section is evaluated based on whether the results are:

- Clearly presented
- Effective format used (tables, graphs...)
- Explained in text
- Explanation logical and consistent
- Refer to supporting calculations
- Emphasize main implications

The above items serve to emphasize that selecting the best strategy for presenting information is part of the project task. It also clarifies that simple presentation of numbers is not sufficient, and that engineers are required to evaluate and interpret the results obtained.

The rating for each element is also clarified:

1. Excellent: perfectly well done and presented. This would be equivalent to scoring between 95% to 100% on the item.
2. Good: the item is present and mostly makes sense. We generally agree with the results though there may be some minor errors. This would be equivalent to scoring between 75% and 95% on the item.
3. Fair: Calculations present and somewhat easy to follow, but process/calculations not 100% accurate. Some significant errors (such as double counting loads) are present. This would be equivalent to scoring between 60% and 75% on the item.
4. Poor: Calculations present and somewhat easy to follow, but process/calculations have substantial errors are present. Alternatively, the process/calculations are so difficult to follow cannot tell if they are really correct or not.
5. Fail: The item is simply not present.

Additionally, comments could be made for each rubric component, overall comments, as well as comments within the project submission. The instructions for utilizing the rubrics emphasized that both positive as well as negative feedback was important.

### CVEN 345

The same basic project utilized in previous semesters is being utilized this Spring 2010. The project involves the static analysis of a three-story steel moment resisting frame structure subject to both gravity and lateral loads. The specific dimensions, section properties, and load parameters vary each time the project is utilized. In this implementation, the building is an office building situated in Seattle.

The project is broken up into 3 parts; this allows for groups to submit intermediate deliverables along the semester. The first two parts of the project are to be reviewed both by the course Teaching Assistant (TA) and another project group in the course, the latter of which performs the Peer Review as a group. Two separate submissions are required from each team so that the reviews can be conducted in parallel. The final portion of the project is due at the last day of classes, so implementing a Peer-Review cycle is not feasible. Rather, at that time the students review their own team performance.

### CVEN 400

The project timeline requires intermediate deliverables along the semester. The 30% submittal documents for the project were reviewed by the instructor, by an engineer/practitioner acting as the client, and another project group in the course, the latter of which performs the Peer Review as a group. Multiple copies of the 30% submittal were required from each team so that the reviews could be conducted in parallel. The final project submission is due at the last day of classes, so implementing a Peer-Review cycle for that submission is not feasible. Rather, at that time the students review their own team performance.

## **Results**

### CVEN 345

The first part of the project focuses on determining the unfactored loads, load paths, and loading diagrams for the various structural members. While this step is arguably the most straightforward, students needed to make modeling decisions such as whether to use one-way or two-way slab behavior and how the external cladding is supported by the structure. The submission is in the form of a short technical report, where the basic outline and sections are given to the students in a template. However, no specific instructions are given on how to present the loads and loading diagrams.

#### *I. Comparison of TA Review and Peer Review*

Both the TA and the peer-groups utilized the same scoring rubrics available for both the report and analysis components. It was important to utilize the same rubric to emphasize the parallel

nature of the review process. However, the TA had more flexibility in utilizing the rubric and could modify it to better suit a team's submission and approach. For example, one of the teams did not explicitly present the loading diagrams for the beams. However, the group had gone beyond the minimum project requirements and determined the shear and moment diagrams. The peer-group assigned a zero score for the diagram component as those drawings were missing. In contrast, the TA penalized the group for the missing diagrams but gave them extra-credit for having the correct corresponding moment diagrams, mitigating the impact of not having the diagrams. The average scores for each rubric component are given in Table 1 below, with the standard deviation presented in parenthesis.

TABLE 1  
COMPARISON TA AND PEER GRADES FOR PROJECT PART 1

Component		TA	Peer	Diff.
Analysis	Organization [30pt]	28.1 (2.4)	25.6 (3.1)	-2.6
	Content [70pt]	62.6 (5.8)	55.8 (10.9)	-6.8
Report	Organization [10pt]	9.7 (0.7)	8.7 (1.1)	-0.9
	Writing [20pt]	20 (0)	15.9 (2.8)	-4.1
	Content [70pt]	64.7 (11.2)	51.7 (15.1)	-13.0
Total		91.8 (6.0)	79.9 (12.8)	-11.9

In general, peers scored more harshly than the TA as indicated by the negative score differences presented in the last column of the table. This is true not only for the class average but apparent when looking at the individual group scores, as shown in Figure 1. Additionally, there was greater variation in the peer scores than those from the TA. This is to be expected as the TA could review all the projects and hold a consistent grading benchmark throughout the process. In contrast, the peer-review groups only had their own previously submitted work as a reference for comparison.

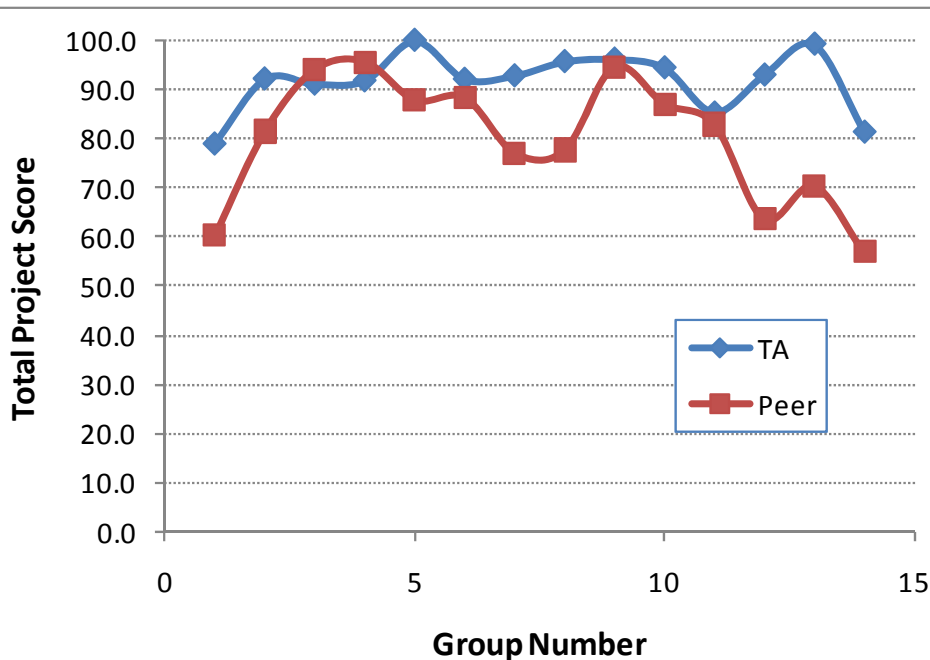


FIGURE 1  
INDIVIDUAL GROUP FINAL GRADES FOR PART 1: TA vs. PEER.



Where students had better agreement with the TA included those components that are fairly straight-forward, such as the organization components. Those sections included consideration of whether all figures were numbered and referred to in the text. In the analysis organization, items included neatly presented calculations, presence of units, and identification of assumptions. These elements are fairly easy to identify and both the TA and Peer Groups did a good job with these components. The differences between the two arose from the assignment of points if something was not perfectly done.

The greater differences occur in the content components, where identifying and evaluating the missing or incorrect elements is more difficult. The good news is that the TA and Peer Groups agreed on the elements that were well done as well as the elements that were missing or poorly executed. Again, the difference came in the assignment of points: “how much is this worth.”

Comments written by peers were typically detailed, particularly in the report section of the submission. Students marked both grammatical errors (such as run-on sentences, verb agreement, use of first person) as well as content comments. For example, when one team utilized the phrase: “We chose to use a theoretical mathematical method to analyze the loads” the comments not only caught the use of the first person but also noted that the phrase “theoretical mathematical method” is vague and needs significant further clarification. Students also complimented when a good section occurred, so comments like “good concise description of wind load procedure” were found.

## *II. Survey of Student Perceptions*

While student perceptions do not fully justify the selection of any single learning activity, they often provide insight into why certain activities work and how they impact their own behavior. The groups received both the TA and Peer-Reviewed submissions and feedback on the same day. They were asked to look over both corrected copies and to remember that the score on the peer-review was not a grade. They were told to reflect on the feedback as well as their own process for performing the review as they would be asked to provide feedback on the process in a survey a few days later. The survey asked students to rank on a scale of 1 to 5:

1. How difficult was it to perform the Peer-Review? (1: Very Easy; 5: Very Difficult)
2. How much did you learn reviewing the work of another group? (1: Very Much; 5: Very Little)

So for both questions, the desirable outcome is 1. However, the scales are slightly different in that the neutral position in question 1 corresponds to a rating on 3, while all the responses for question 2 correspond to learning gains. The results from the survey are presented in Figure II below, where the number of responses for each scale level is given in the table. In both cases, the results are skewed toward the positive end of the choices: students in general found doing the review not difficult, with an average response of 2.58, and felt they learned something from the process, with an average response of 2.21. While the numerical averages are somewhat close, due to the nature of the scale the responses for learning gains are actually significantly more positive.

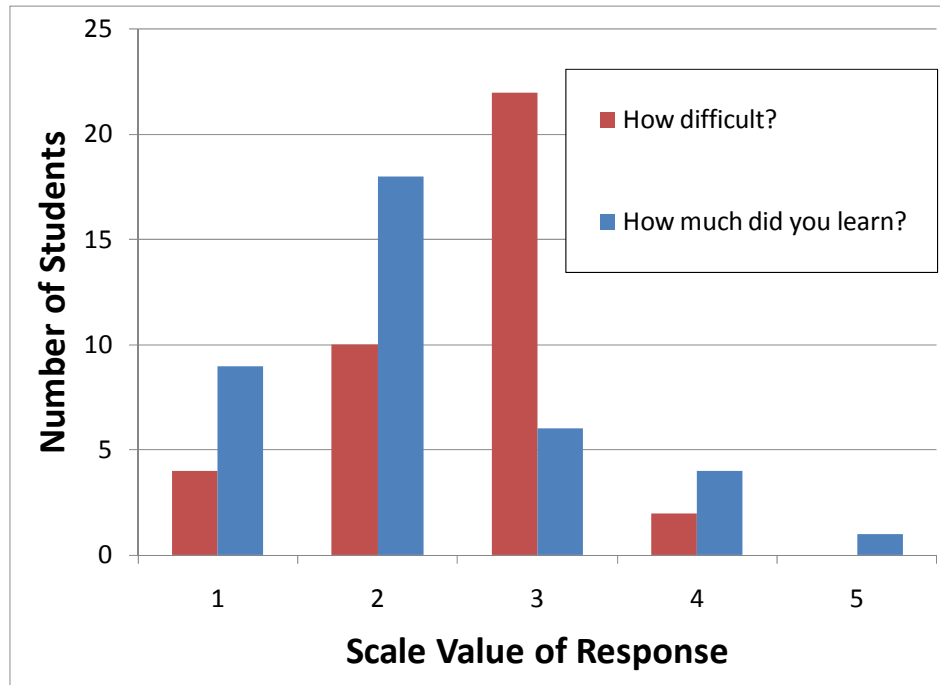


FIGURE 2  
RESPONSES FROM STUDENT SURVEY ON PEER REVIEW CYCLE.

The students were also asked to comment on what they learned from performing the review. In general the comments also reflected that doing a review was a useful exercise, as well as gave perspective on how the grading process works. For example, a sample comment was:

“How hard grading must be and how mean of a grader I am. I got to see another approach to calculations. Was a useful tool for our beginning engineering abilities.”

The most frequent topics and sample comments include:

1) organization of information,

- “I learned good and bad ways of organizing information in terms of the readers' understanding.”
- “It was crucial to see how things were organized and how this affected the ways to understand the project”

2) presentation of information/data,

- “I learned that even though our group may understand what we write down, it doesn't mean someone else will fully understand our examination or method”
- “I learned other creative ways to demonstrate data. Tables in excel for example”

3) analysis approaches.

- “I learned different ways that the project can be looked at and analyzed”
- “I found mistakes in my work, by looking at other people's work”
- “We could see parts of the project that we could have done a different & more effective way by looking at the way the other team did their project”

- 4) teamwork skills,
- "...the importance of working wholly as a team so the project flows completely."
  - "Have multiple people read over so the idea you're trying to convey is clear"

The first three items and related comments indicate that the students are utilizing this process not only to learn the material but also to think about their own approach to the various problems presented in the project process. These are then indicative that the peer-review cycle is providing a mechanism for students to enhance their metacognitive skills.

The students also provided feedback on the usefulness of the feedback received from both the TA and the Peer-Review group. As expected, the students strongly valued the feedback from the TA as being more correct. They also in general also found the Peer-Review feedback to be helpful. Some sample comments are:

- "Very (helpful), gave explanations of why they graded everything the way they did."
  - "It was helpful because it provided an alternative viewpoint and helped us realize where some of our mistakes were made."
  - "Very helpful towards revision and future tech. writing."
  - "Very helpful to hear from other students & easy to understand. It helped us focus more on details and make our calculations easier to follow."
- "It was very helpful. It showed me some mistakes I made and caused me to consider things I had not considered yet."

Even though the scores received from the Peer-Review will not be included in their grade, students are still highly sensitive to those numbers. They perceived the review as being harsher than that of the TA, though in general the comments and identified weaknesses were actually the same. Some sample comments:

- "There was definitely helpful feedback, but it was sometimes buried in the high volume of nit-picking or personal preference."
- "The peer feedback was good to know, although a bit harsh."

### CVEN 400

Students were surveyed regarding their experiences in conducting and receiving the peer review. Students reported a variety of topics when asked what they learned from completing a peer review, a few focused on learning content better or realizing a mistake they had made, however, most reported revelations such as:

- I realized how important it is to be completely clear when presenting an idea... If a classmate cannot understand the concept, a client will definitely not be able to understand.
- ...sometimes one can become close minded and unable to think outside of ones original idea  
I also learned that it is painfully obvious when a report was rushed
- Saw how difficult it can be to understand an idea if it is poorly presented
- It is best to have someone double check your work ...
- That we need to take time outside of class to organize the entire project better

Students also were asked to rate level of difficulty and how much they learned using a Likert scale. A score of “1” is best for all bars shown in the figure shown below, 1=very easy for the “How difficult?” ratings & 1=very much for the “How much did you learn?” ratings. It is amazing that no one found it “difficult” to do the peer review, nor did anyone learn “little” or “very little” from the process of completing a peer review.

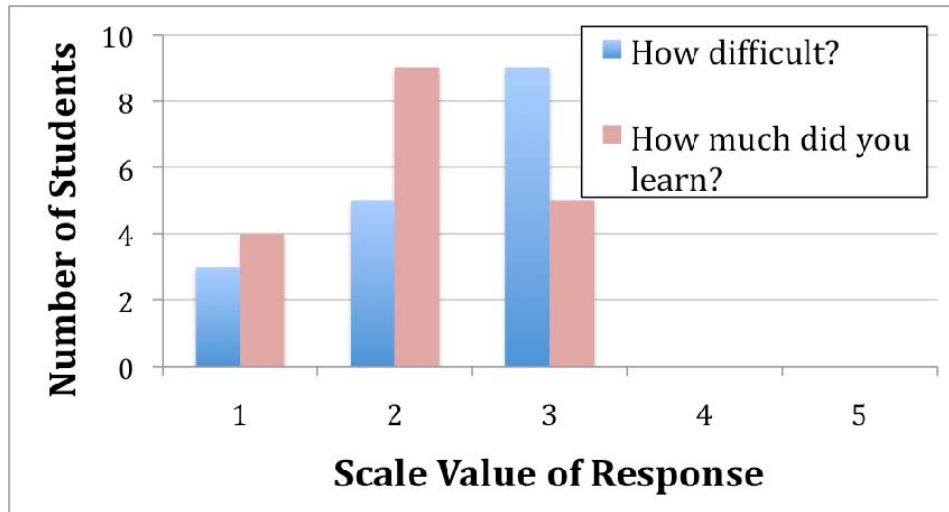


FIGURE 3  
HISTOGRAM OF SURVEY RESPONSES.

The above results focus on the process of completing a peer review – both “How difficult is it to complete a peer review?”, and “How much did you learn from doing a peer review?”

Another measure of the usefulness of a peer review is “How much did you learn from receiving the comments received from a peer review of your project?” In this case, it is useful to view their responses from two perspectives. First, those receiving the best feedback (in the opinion of the instructor) placed a high value on the feedback, whereas those receiving less valuable feedback (again based on instructor judgment) placed less value on the feedback. A second, and perhaps more valuable perspective, can be achieved by comparing the value placed on the feedback *compared to the value placed on feedback obtained from an engineer practitioner (acting as an informed client). It should be noted that the same engineer provided feedback to all teams AND the students were unaware of the identity of the consultant at the time of the feedback. A sample of matched pairs is presented in Table 2.*

The comments above are representative in terms of their relative frequency and content. Across the board, students valued owner feedback, as that was seen as providing exact guidelines on expectations. This is particularly true as this owner gave very specific and detailed feedback to the teams. Peer feedback was generally helpful, though as clearly remarked by student D the performance of the review was more useful than the feedback received. Comparing the usefulness of the two types of feedback is difficult, as the students perceived them very differently: owner feedback constituted “instructions” while peer feedback was “advice.”

TABLE 2  
REPRESENTATIVE STUDENT COMMENTS

Group	Comment on student feedback	Comment on <i>client</i> feedback
A	Moderately helpful, it was good to see where we were being unclear or confusing	Very – they are who this project is designed for so everything they mentioned is addressed
B	Very helpful. They pointed out some flaws that we will have to correct	Very detailed. We now know the exact direction our team needs to go...
C	Pretty helpful; the other group caught some errors ... which ended up changing our layout quite a bit.	The clients feedback was even more helpful because it gave us better insight as to what he wanted.
D	I believe it was helpful but not to the extent that looking at another teams design was.	Very helpful! The clients feedback helped enforce the basic goals that our group had strayed from a little.
E	Not terribly helpful. We did not receive any major comments/ changes.	Very helpful. These comments help us hone in on what we need to do to meet the client's expectations
F	It was moderately useful. However, the recommendations were not exactly in compliance with the design standards...	The clients suggestions were very good and made us aware of things that we had not considered ... our client took so long to get back to us ... we had to backtrack ... otherwise we loved the suggestions

**Summary, Observations and Conclusions:**

Students can do meaningful peer-review (even of a broad civil engineering project), while they are limited in what they can do in grading – they do not have the experience to judge partial credit well, they provide very good feedback and assessment. Overall, the students were correct and not overly negative in feedback. Additionally, students were in general much more detailed in their comments about what was wrong and how to improve. The resulting review and feedback from the peer-review process provide very good formative guidance and provide continuous improvement to the project.

The students perceived many benefits of performing the peer review (in addition to receiving helpful information from their peers). They saw value in seeing how another group in their class approached the same problem. They were able to analyze varied approaches to presentation and organization (critical components of the process). They realized that the *real* benefit of peer review was obtained by critically analyzing and evaluating the work of another team (as opposed to merely receiving feedback from another team). The range of feedback provided varied greatly, depending on the range of students's skills and how students self-selected into teams. Students clearly identified and valued thoughtful feedback.

The student comments also indicate that the peer-review cycle is providing a mechanism for students to enhance their metacognitive skills as they reflect more critically on their learning, which is one of the desired outcomes from the peer-review cycle. The process provides a mechanism for the students to become aware of what they were learning during the project process. This results in an increased sense of responsibility for their learning (another of the targeted outcomes for the peer-review cycle). Students also gained an appreciation of the difficulties inherent in the grading process: both in evaluating as well as providing feedback. While this was not an explicitly designed outcome for the introduction of the peer-review process, it is an unexpected and welcome additional outcome. As the students gain a better understanding of the grading process, better communication between instructors and students can result.

### Bibliography

- [1] Bonwell, C.C., and J.A. Eison, "Active Learning: Creating Excitement in the Classroom, Washington, DC ASHE-ERIC Higher Education Reports, The George Washington University, 1991.
- [2] Capon, N., and D. Kuhn, "What's so Good About Problem-Based Learning?," *Cognition and Instruction* Vol. 22, No. 1, 2004, pp. 61-79.
- [3] Daniels, M., and A. Hauer, "Balancing Scaffolding and Complexity in Open Ended Group Projects", *ASEE/IEEE Frontiers in Education Conference*, Milwaukee, WI, 2007.
- [4] Kelly, K., *Out of control: The new biology of machines, social systems, and the economic world*, Reading, MA: Addison-Wesley, 1994.
- [5] Mathie, V.A., B. Beins, L.T. Benjamin, M.M. Ewing, C.C.I. Hall, B. Henderson, D.W. McAdam, and R.A. Smith, "Promoting active learning in psychology courses," *Handbook for enhancing undergraduate education in psychology*, Washington, DC: American Psychological Association, 1993, pp. 183-214.
- [6] Wilson, B., and M. Ryder, "Dynamic Learning Communities: An Alternative to Designed Instructional Systems", *Proceedings of Selected Research and Development Presentations at the 1996 National Convention of the Association for Educational Communications and Technology*, Indianapolis, IN., 1996.
- [7] Blumenfeld, P.C., E. Soloway, R.W. Marx, J.S. Krajcik, M. Guzdial, and A. Palincsar, "Motivating project-based learning: Sustaining the doing, supporting the learning," *Educational Psychologist* Vol. 26, No. 3-4, 1991, pp. 369-398.
- [8] Anderson, L.W., and D.R. Krathwohl, (Eds), *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*, New York, NY: Addison Wesley Longman, 2001.
- [9] Forehand, M., "Bloom's Taxonomy: Original and Revised", *Emerging perspectives on learning, teaching, and technology*, 2005, pp. 1-9. <http://eit.tamu.edu/JJ/DE/BloomsTaxonomy.pdf>.
- [10] Luckie, D.B., J.J. Maleszewski, S.D. Loznak, and M. Krha, "Infusion of collaborative inquiry throughout a biology curriculum increases student learning: a four-year study of "Teams and Streams", *Advances in Physiology Education* Vol. 287, 2004, pp. 199-209.
- [11] Bransford, J.D., A.L. Brown, and R.R. Cocking, *How People Learn: Brain, Mind, Experience, and School*, Washington, D.C.: National Academy Press, 2000. [http://www.nap.edu/catalog.php?record\\_id=9853](http://www.nap.edu/catalog.php?record_id=9853).
- [12] Carlson, P.A., and F.C. Berry, "Calibrated Peer Review and Assessing Learning Outcomes", *Proceedings of 33rd Frontiers in Education (FIE) Conference*, 2003, pp. F3E-1.
- [13] Cho, K., and C.D. Schunn, "Scaffolded writing and rewriting in the discipline: A web-based reciprocal peer review system," *Computers & Education* Vol. 48, No. 3, 2007, pp. 409-426.