Peer Review: Modeling Civil Engineering Practice, Another Way To Improve Learning

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Abstract

This paper presents the initial results of a research project designed to foster in students the habit of checking their work for accuracy. The problem observed was that students seemed to regard their homework submissions as simply a product to be handed in, and the correctness of their solutions did not seem to concern them. This struck the author as the wrong approach in educating future Civil Engineers (and Army Officers in our case).

In the spring of 2004, the author instituted a system of mandatory collaboration in the Structural Analysis course, through forced "peer review" of all individual work. This became, similar to structural design, an iterative process of working towards achieving the following goals to increase student learning:

- from their classmates
- from having to explain their own work
- from correcting mistakes and errors in others' work
- from learning their own abilities and limitations
- by modeling the professional aspects of having work reviewed for correctness

This paper discusses the initial results from the two iterations of this procedure, as well as the revisions in the procedure introduced for the Spring Term of 2005. In addition, the author will provide an assessment of learning outcomes as well as student attitudes toward the procedure and perceived value of "peer review" as a learning tool. The author found that after two semesters of using Peer Review 56% of the students indicated that peer review had a positive effect on their learning and another 28% provided a response that indicated that it was only the mechanics of the process used that limited their success; largely due to their peers not being able to provide a timely review. When asked if they would use peer review for other assignments (when not required), 61% indicate they would and another 22% said they would some of the time, only 17% indicated they would not. In end of the course assessments a positive trend in this course was also noted in two questions dealing with students being made responsible for their own learning and learning from their fellow students. Results are based on student surveys of those who had used peer review compared to other years without peer review. Finally this paper discusses future work on this project to validate the value of "peer review" as a learning aide.

Introduction

Civil Engineering by its nature often involves design of one of a kind structures that must serve the public. These structures must be designed, without prototype, to maintain the public's safety, i.e. not fail. Getting it right is critical! This is a fact that has been recognized since the earliest written laws: Hammurabi's code stated as early as 1780 BCE "229 If a builder build a house for some one, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death" [1]. There are several other laws, numbers 230 through 233, that deal in a similar vein with building failure and offer similar dire consequences in an effort to stress the importance of getting it right. Today while we do not threaten engineers or their family members with death as Hammurabi did, we still do hold the profession to high standards and expect the civil engineer's work to be correct. Work that firms produce is checked in-house and certified, "stamped," by responsible licensed engineers, signifying that it has been reviewed and is correct, i.e. safe and able to perform its intended objective, before it leaves the firm. It follows that our engineering students need to be trained and initiated in this standard if we expect them to adhere to it as practicing members of the profession after they graduate. "University courses are the preparatory stage to a profession and should therefore encourage learning that reflects the way in which professionals continue to learn and work."[2]

After returning to teaching in the fall of 2003, after a six-year break, the author noted that his students were not exercising the level of care with their assignments that should be required of young engineers. The author taught seniors taking Advanced Structural Analysis that semester, a group who should have been well along their way in adapting the customs of the profession. Not to suggest that the consequences of submitting a wrong assignment were dire, but it seemed reasonable that some more advanced level of care and concern should be exercised with their work, especially from students near the end of their undergraduate studies. The problem he observed was that students seemed to regard their homework submissions as simply a product to be handed in, and the correctness of their solutions did not seem to concern them. This struck the author as the wrong approach in educating future Civil Engineers (and Army Officers in our case). Influenced by much research on the subject, the author also believed that students should be more responsible for their own learning as well. If they were to truly learn the material, they must take more ownership of it and see it as more than a requirement to be met and endured.

While participating in the Master Teacher Program at the U.S. Military Academy, the author came across some work that suggested that one way to develop a student's metacognition, thus their ability for life-long learning, is to view them and treat them as novices in the profession.[3] There is also a large body of research that indicates that students can achieve more when they are working and learning cooperatively.[4-13]

> Weak students working individually are likely to give up when they get stuck; working cooperatively, they keep going. Strong students faced with the task of explaining and clarifying material to weaker students often find gaps in their own understanding and fill them in. Students working alone may tend to delay completing assignments or skip them altogether, but when they know that others are counting on them, they are often driven to do the work in a timely manner. [14]

Other research shows that students learn better in small groups, especially if they are structured and deal with assigned readings and problem sets.[15, 16]

Armed with this view of what should be and a few ideas from research of how to improve student learning, the author clearly knew something must be done. The challenge was to find a way to make the students, at a minimum, check their work prior to turning it in, and hopefully improve their learning and develop their metacognition as well. This seemed to be a simple enough task, yet of course it was not.

Like all engineering design, developing a system to improve the students leaning and checking on their work was an iterative process. Each iteration produced results that led to revisions and modifications. Bit by bit, the author was hopefully coming closer to the "final design".

First Iteration

During the spring of 2004, the author instituted a system of "mandatory collaboration" in the Structural Analysis course, through forced "peer review" of all individual work. The goals were to increase student learning by:

- having students learn from their classmates
- having to explain their own work to others
- correcting mistakes and errors in others' work
- recognizing their own abilities and limitations
- modeling the professional aspects of having work reviewed for correctness

It was also desired that as the students identified errors they would gain skill in error tracking, finding the source of their errors and becoming more independent in their ability to check their own work. A non trivial collateral benefit, especially for those who like the author do not have access to TAs or graders to do grading, would be that grading would be come much simpler if all the students had corrected their mistakes prior to turning in their homework--or so it was hoped.

The author quickly put together the first iteration of peer review. He rather naively thought (or hoped) that a few simple instructions were all that would be necessary, the students would likely accept this (although grudgingly at first), some survey data would show that this was a great teaching system, and life would be better for all parties. Naturally this "pie in the sky" view did not correlate to the reality observed. This was first instituted in the Structural Analysis course, a required course for civil engineering majors that had 41 juniors enrolled. The idea of peer review was presented in a portion of the course administrative letter which stated:

In order to insure correctness, this semester I will often require you to consult with your classmates, or myself, and have them sign off on submissions to signify they are in agreement with your work. The goal is to have you check your work and learn from your classmates (peer review) as well learning from having to explain what you did. This is probably something new for most of you, but is a valuable part of your learning. It is critical that you show all of your work and leave "foot prints" so that it can be easily followed.

They also were given a place on a table of contents sheet for each assignment to have other students initial that they had checked their work.

Initial results from observations proved the folly of the author's expectations of how this would work. While some students did fulfill all expectations, the author observed several students, directly in front of him and unashamedly, holding out a paper to classmates just prior to turning it in and saying, "Sign this and I'll sign yours." This was done with no effort to correct, or even look at, the work completed. There was also evidence of some students signing off on work as correct that was clearly not correct, and should have been readily recognized as such, due to the fact they themselves submitted correct work. Still others signed off on work that they themselves had not completed, making an accurate check nearly impossible to make. Clearly this was not the desired effect. The author's goal was never to devise a meaningless administrative requirement to turning in homework, yet for some of the students this clearly was all that was happening. The author did take class time to more fully explain the concept of peer review as he envisioned it, and slightly modified the statement students were required to initial, in the hopes getting a more cooperative response. Penalties were also assessed for not having work reviewed.

The author also surveyed the students mid way through the course, roughly at the one-third and two-thirds points, after exams, to gauge their view of the peer review policy. The results were clearly mixed. While some students did see the value to it and were glad to have the requirement to check their work, others saw it as nothing more than an additional administrative burden and a waste of their time. Some students indicated that they would check their work with a classmate regardless of the requirement to do so. The data collected showed that 50% of the students did not see the value in the process or viewed it as just another administrative requirement.

As the semester progressed, the author did note a glimmer of hope as he started to note that a significant number of students cited the help of their classmates in correcting their work. At the Military Academy all outside assistance received on any work turned in must be documented and acknowledged in order to conform to the strict tenets of the Honor Code. Often citations to the effect, "Joe Doe explained to me that I had the wrong value here, and I now understand why it was wrong; I used the correct value, re-did the rest of the work on my own, and our solutions matched" were observed. Clearly this was the type of result the author was hoping to achieve. While the process was not a total success, the author was encouraged that some of the students were clearly benefiting from the peer review system.

At West Point all students complete course-end surveys in all their courses. This is a unique, web-based system that has a series of Academy-wide questions, as well as questions that are department and course specific. In the course-specific questions, the students were also asked directly about peer review in the course and their opinion of its value. Table 1 shows the results of these questions. Two questions that are given Academy wide deal with students being responsible for their own learning and learning from their fellow students. These questions are posed as statements and students rate their agreement on a scale, with students strongly agreeing (5), agreeing (4), being neutral (3), disagreeing (2) or strongly disagreeing (1). In both these areas a slight increase was seen over previous semesters, see Table 2. Of course these scores were fairly high to start with, so the significance of the gain is open to debate and while this

cannot be shown to necessarily be a direct result of the peer review requirements, the author believes it can be inferred to be at least partly responsible for this increase.

Question	Agreed	Neutral	Disagreed
Peer Review helped in turning in better homework	53%	25%	22%
Peer Review helped learn more in the course	36%	38%	28%
Peer Review is a valuable learning tool	40%	40%	20%

Table 1 Student Survey Results, Peer Review Questions

Statement	Previous Semesters Average	04-2 Average
This instructor encouraged students to be responsible for their own learning.	4.61	4.68
My fellow students contributed to my learning in this course	4.37	4.53

Table 2 Student Survey Results, General Questions, Semester 04-2

Second Iteration

Hoping to avoid the pitfalls of the past and to make peer review truly a more valuable tool for students, the author revised the system when he taught Advanced Structural Analysis in the Fall of 2004. This course is an elective for seniors, and the 18 students in the course were all students who had taken Structural Analysis with the author the previous semester and thus had been exposed to peer review. The class was mix of the students who had done very well in Structural Analysis as well as those who had done poorly; in fact, the three cadets from the previous semester with the lowest grades signed up for the course. The following statement was handed out to students at the beginning of the semester to explain the policy to them. It was presented as a separate handout, not just a portion of the course policy memorandum, and it was also the second semester they would have seen the peer review requirement.

The objective of PEER REVIEW is two fold. First and primarily it is to help increase your learning and knowledge of a subject by having you review work of your classmates as well as requiring you to have to explain your work to them. It is hoped that when disagreements in answers are encountered you will take the time to discuss them and find the error, correct method, or solution. In order for this to happen you must prepare your work in a timely manner in order to allow it to be adequately reviewed. Finishing the work 15 minutes prior to turn in will not allow enough time! The second reason for peer review is to also emphasize that it is important in Civil Engineering to take the steps necessary to get the correct answer. Remember Hammurabi's Law? In practice plans, drawings and specifications are reviewed and a responsible licensed PE is required to stamp them. In academia publications and research are also subjected to peer review.

Based on our experience with PEER REVIEW in CE 403 I feel a few changes are necessary. In an attempt to make PEER REVIEW more rigorous and a better learning tool the following procedures will be in place.

1. You will sign up with a peer review team. These teams will change every couple of Problems Sets. The only requirement for your team is it be people who have not previously been on your team.

2. You will be penalized for providing a bogus peer review. Examples of bogus peer review include, but are not limited to:

- *Checking off on work you have not done yourself.*
- *Checking off as correct work that is wrong, yet you got correct.*
- *Checking off on work with very basic and obvious deficiencies.*

3. You will be penalized for not having peer review completed or not being able to provide peer review because you have not completed the work in a timely manner to allow for peer review. This circumstance should be noted on your problem set.

4. You will not be penalized if your peer review team all comes up with a wrong answer, assuming you all think it is correct and that is a logical assumption based on the work shown.

5. Similarly you will not be penalized if after review you all think the other's work is wrong and no one can convince the other members to change their answers. This rare case must be fully explained by all parties however, with reason why you are convinced your answer is correct.

6. You will not be penalized if you completed your work but none of your team is able to provide peer review because they have not completed their work in a timely manner. Be sure to note this and provide the details.

Remember, ideally you will all only provide genuine and accurate peer review, so there should be no penalties.

In this iteration the author clearly was reacting to the past semester's problems and hoping to avoid them. The emphasis of the changes was clearly was to eliminate the cursory or in name only reviews by imposing some penalties. In reviewing his reaction to the past semester's problems, the author inadvertently wrote a policy statement that in retrospect seems somewhat negative and punitive in tone. Clearly his desire was to eliminate the "I'll just sign anything" response of students. The establishment of groups was designed to make the review more purposeful, and hopefully encourage students to work ahead of time and feel responsible to their group. The changing of teams throughout the semester was designed to ensure complete involvement of all class members, as well as to mix things up and avoid the effects of some members being left out or negative aspects of group dynamics being developed in teams.

An observation of homework submissions indicated the process was meeting with more success than the previous semester. Some students clearly continued to like the idea and appreciated the incentive to check their work for accuracy. The author also observed much more documentation of help received during the review process, but he noted that not everyone had yet bought into the approach. The author observed a few cases of students who would take the 5% cut for not having peer review done at all. He also noted that there were cases of students writing notes to the effect, "My work did not match my reviewer's work, but I could not find the error." Closer inspection of these comments usually found that peer review was almost always done within the 15 minutes prior to the turn in deadline, thus allowing no time for reflection on the review or corrective measures. One of the positive results the author did note after the initial assignments

was that the students would not sign off on incorrect work; they would note the problems with it or they would indicate work that was not complete at time of the review. During the first assignment, several students whose work was correct were penalized for signing off on other's work that was not correct. Apparently this word got out and seemed to fix the problem on future submissions, and the bad habit of the previous semester was broken. This in itself was success, yet at admittedly a low level.

At the conclusion of the semester, the students filled out the end-of-semester course survey. As part of the course-specific questions, they were given three, open-ended questions dealing with peer review: How did PEER REVIEW help you in learning the material? Do you have any suggestions for me to make PEER REVIEW more valuable for cadets in the future? Will you use PEER review for future assignments, even when not required? Table 3 summarizes the results of these questions. These results, although with a smaller sample, do reflect a much improved acceptance by the students of peer review. In answer to the first question, the 28% deemed in the middle provided a response that indicated that it was the mechanics of the process used that limited their success, largely due to their peers not being able to provide a timely review.

This seems to imply that they did acknowledge the worth of the process, even if its impact was somewhat limited. One typical comment shows the students' recognition of the benefit of the process: "*Peer review was definitely key in helping me learn the course material on the problem sets-- when I didn't know how to apply something I learned in class, my peers were usually able to help me figure out what I was doing wrong, and how to correct it, which helped me learn more about the subject overall."* The fact that the clear majority readily indicated they would use it even when not required, and the 22% in the middle indicated they would some of the time, demonstrates the acceptance of this process as helpful in their studies. The responses to the call for suggestions to improve peer review dealt largely with ideas for allowing more time for review, the mechanics of having time to allow for review, and allowing more freedom in picking groups. Only one response suggested eliminating peer review.

In the Academy-wide questions, a positive trend was also noted on the two questions dealing with students being made responsible for their own learning and learning from their fellow students. Both showed a positive delta from the average score of the previous seven years and were, in each case, the highest score recorded (see Table 3). The author found these results very encouraging. Although admittedly the sample was small, only 18 students, the trends were positive, and clearly most students liked or recognized the value of peer review and found if valuable. The majority of the negative responses indicated that they that were due to the mechanics of making the process work, rather than the process itself. It should be noted that there were a few comments that could be typified by the following: *"It helped a lot, but that doesn't mean I have to like it."* The author clearly has not yet created 100% willing converts, but progress has been made. While hoping to see an improvement in the final exam grade average from a very similar exam used in previous years, none was observed. Overall course grades were higher, due to higher problem set grades, which were helped by having mistakes corrected prior to turning in the work.

Question	Positive Response	In the Middle	Negative Response
How did PEER REVIEW help you in learning the material?	56%	28%	16%
Will you use PEER review for future assignments, even when not required?	61%	22%	17%

Table 3 Survey Results, Course Peer Review Questions Semester 05-1

Statement	Previous Semesters Average	Current
This instructor encouraged students to be responsible for their own learning.	4.68	4.94
My fellow students contributed to my learning in this course	4.35	4.55

Table 4 Student Survey Results, General Questions Semester 05-1

Third Iteration

While the author was pleased with these initial results and remained convinced that peer review is the way to go, he realized he still had not found the final solution to accomplish this. The problem surfaces when he reads peer reviews that say to the effect, "My work is wrong, but I can't find the error," and he sees it was reviewed just minutes prior to turning it in. On the other hand, there are a significant number of cadets who clearly benefit, as he continues to see numerous documentation statements that indicate students are making corrections and understanding why they were needed. As the author sees it, the challenge is two-fold. First, it is to sell, or adequately market, this methodology to students as a valuable learning tool, as well a practice that is necessary in the discipline. The second is to set up a structure that inspires the students to actually conduct peer review as it is intended and needs to be done. This involves insuring that there is time for the students to review the work of others and reflect on their reviewed work and make changes if necessary.

In a blinding flash of the obvious, the author submitted his policy to peer review, prior to having it passed out to a new group of students in the spring semester of 2005. This is a group of students that would not have been exposed to this process in previous engineering courses. It only seemed logical that the author could benefit, as he hoped his students would, from a review of his work and ideas. The author consulted with Dr. Anita Gandolfo, Director of the Center for Teaching Excellence, COL Stephen J. Ressler, P.E., the Deputy Head of the Department of Civil & Mechanical Engineering and a noted engineering education guru, and MAJ Brad Wambeke, P.E., an instructor also in the Department of Civil & Mechanical Engineering who has previously taught Structural Analysis and will again be teaching it with the author this spring.

Feedback from my reviewers suggested six changes. First, the author learned that "peer review" is not an optimal name choice for the process because it is used often in a freshman-level humanities course where the cadets often dislike both the process and the course. The author's reviewer believed that my students' negative responses to the process might even have been influenced by their prior experience of a different process with the same name.[17] Second, his

reviewers suggested that the tone of my instructions should be less punitive in nature. Third, it was recommended that the tie to professional practice be emphasized as a main reason for this procedure. Fourth, students' own assessment noted that the policy would work better if there was more time to review the work prior to the submission deadline. Fifth, despite the recognized benefits of assigning groups[18] students and reviewers pointed out the unique structure and time restraints on cadets at West Point that create inherent difficulties with assigning groups. Sixth, his reviewers suggested a more formal process of recording reviews and reminding them exactly what the review should accomplish. Thus, for this semester, students received the following instructions:

DESIGN REVIEW POLICY

It is important in Civil Engineering to take the steps necessary to get the correct answer. Remember Hammurabi's Law? In the "real world" practice plans, drawings and specifications are reviewed and a responsible licensed PE is required to stamp them. In academia publications and research are also subjected to peer review prior to publication.
Thus, this semester all your problem sets will be reviewed by two of your classmates prior to their being turned in. This approach to having your work reviewed is called DESIGN REVIEW, and this idea, if not our process, may be familiar to you from other courses. The objective of DESIGN REVIEW in our course is two fold. First and primarily, it is to help increase ***your*** *learning and knowledge of structural analysis by having you review work of your classmates, as well as requiring you to have to explain your own work to them. It will also give you a good idea of your relative strengths and weaknesses in the various topics we will cover this semester. It is expected that when disagreements in answers or approach are encountered you will take the time to discuss them and determine if an error or misunderstanding of a concept does exit, and if so how to correct it. In order for this to happen you must prepare your work in a timely manner in order to allow it to be adequately reviewed. It must also be clearly presented to allow your reviewers, your classmates, to easily follow it. design !*

So how will we incorporate DESIGN REVIEW into CE403? Remember the goal is to help you learn the material more completely. As an incentive to make sure that you treat this part of the assignment as importantly as the calculations and other work you do, DESIGN REVIEW will count 10% of the possible grade on each assignment and provide an opportunity for you to earn additional points as well. Each of you must provide two design reviews of each assignment and have your work reviewed by two different people. You are encouraged use many different reviewers throughout the course, and may not use the same reviewers for consecutive assignments. You will notice that each assignment has two deadline attached to it. The first is the time you are required to have the work and design review completed. The second time, typically 1 day later, is the time the work is to be turned in for grading. This will allow you to go over the design review comments, make changes to your work, or decide that no changes to your work are necessary.

How do you conduct a DESIGN REVIEW? First you must have completed the work in order to review your classmate's work! There is a DESIGN REVIEW Sheet (see Figure 1) provided with each assignment, a copy of which is attached here. This sheet will have a space for each reviewer to annotate the time they reviewed the work and the results of their review. It will also

have a place for you to write down what action you take after the review is completed. So what are you looking for? Certainly you are looking to see if the "final answer" is correct, but more than that you are checking to see if the work follows and applies the appropriate theory and methodology, is it clearly presented, does the work makes sense, is it complete, and finally ***do the answers make sense*** *(this is hugely important for you as a budding engineer!).*

What is not helpful in this process? Providing a bogus DESIGN REVIEW; examples of bogus DESIGN REVIEW include, but are not limited to:

- *Checking off on work you have not done yourself.*
- *Checking off as correct work that is wrong, yet you got correct.*
- *Checking off on work with very basic and obvious deficiencies.*

In the unlikely event that a bogus DESIGN REVIEW takes place, the reviewer will be penalized. You will not be penalized for a bogus DESIGN REVIEW if your design review group all comes up with a wrong answer, assuming you all think it is correct and that is a logical assumption based on the work shown. Similarly, you will not be penalized if after review you all think the other's work is wrong and no one can convince the other members to change their answers. This rare case must be fully explained by all parties, however, with reasons why you are convinced your answer is correct. Remember, ideally you will all only provide genuine and accurate DESIGN REVIEW, so there should be no penalties. Especially good design reviews, those that are thorough, clearly provide meaningful comments that will help the engineer, offer insight, and demonstrate the reviewer's care and understanding will be given bonus points. In addition, at the end of the semester, we will have awards for the top Design Reviewers.

The author hopes that these revisions will make peer review and its objectives clearer, more acceptable to the students, and will truly become an aid in their learning, both in this course and after. The ultimate goal is to set them up for life-long learning as they go on from the Academy. It is hoped that the achievement of these goals will be reflected in higher grades in the course and an increased ability to understand structural analysis, as well as to apply it in follow-on design courses.

REVIEWED ENGINEER:_____ Problem Set:_____

DESIGN REVIEW 1 Date/Time Review Completed:_____

Does the work follow and apply the appropriate theory and methodology? YES ☐ NO ☐ Explain below

Is the work complete and easy to follow? YES ☐ NO ☐ Explain below

Do the answers make sense? YES ☐ NO ☐ Explain below

REVIEWER COMMENTS:

REVIEWED BY:_____ Initials:_____

DESIGN REVIEW 2 Date/Time Review Completed:_____

Does the work follow and apply the appropriate theory and methodology? YES ☐ NO ☐ Explain below

Is the work complete and easy to follow? YES ☐ NO ☐ Explain below

Do the answers make sense? YES ☐ NO ☐ Explain below

REVIEWER COMMENTS:

REVIEWED BY:_____ Initials:_____

ENGINEER'S COMMENTS:

Figure 1 Design Review Sheet Example

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16. Glaser, W., *The Quality School--Managing Students Without Coercion.* 1990, New York: Harper Perennial.

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