Student Mastery of Engineering with Design Review

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Abstract

Traditional structural engineering pedagogy has consisted of students preparing for class by reading a textbook, followed by a professor giving a lecture, followed by students doing individual homework. Students received feedback in terms of a grade from the professor, and, ideally, the student filed the graded work and possibly reviewed it again before an exam. Following the exam, the professor moved to the next topic and essentially ended any further contact time with the material, resulting in students quickly dumping a good percentage of what was learned. To make matters worse, most faculty would agree that undergraduate students often skip the reading prior to class, and studies have shown that almost half of all students do not pay attention to material presented during a lecture. Thus, it is critical for engineering educators to improve the stagnant method of traditional teaching and learning. Small mistakes in the engineering profession can lead to death or millions of dollars in repair.

For the fall 2018 semester, in the Design of Steel and Wood Structures at the United States Military Academy at West Point, Civil Engineering students participated in a cooperative learning technique aimed at improving student learning. These same students tried a different version of this technique in Structural Analysis the prior semester.[1] Prior to submitting individual homework to the instructor for grade, students paired up with a peer within their class hour and checked each other's work using an instructor provided "Design Review Sheet." When a student found a mistake, or disagreed with the methodology used by their Design Review partner, the student annotated this on their sheet. The expectation was that when disagreements were discovered between students, they would discuss with each other where the error or misunderstanding existed and subsequently corrected the error prior to submission for grade. This not only required students to explain the work they completed, but it also provided additional contact time with the material.

With respect to Engineering Teaching and Learning, Design Review provides the essential cooperative learning characteristic of positive interdependence because individual student learning increases as review partners improved in their Design Review. As a student incentive to complete a thorough review, the quality of review counted for 10% of each assignment. Efforts this iteration were in response to some of the student suggestions following a previous iteration.[1] This iteration, in lieu of students turning in their work in pairs to receive one grade, each student would turn in their individual work and Design Review sheet. This was done to hold all students accountable for the work they completed. In addition, the instructor provided Design Review sheet was modified for clarity and the requirement to write a memorandum summarizing the results of each Design Review was eliminated. This cooperative learning technique was used on six of seven homework assignments during the term and on seven of nine homework assignments in their pre-requisite course. Student feedback was collected from both Likert Scale questions and open-ended questions. This paper will make the case that this pedagogy benefits Engineering Teaching and Learning by:

(1) getting engineering students in the practice of what engineers in practice already do (check each other's work),

(2) increasing student learning of course learning objectives through repetition and through observing how others solve problems and present their work, and

(3) improving the ability of future engineers to communicate their work clearly and effectively.

1. Introduction

In the day-to-day analysis and design of new infrastructure, the structural engineering profession is one that is recognized for not making mistakes. The first Fundamental Canon from the National Society of Professional Engineers (NSPE) states that engineers must "hold paramount the safety, health, and welfare of the public"[2]. This unwavering demand for perfection by

society requires all engineer graduates entering the profession to acquire specific "knowledge, skills, and behaviors."[3] Unfortunately, even the most brilliant minds in the world cannot escape the reality that no one is perfect. The I-35 Bridge Collapse in Minnesota and the Hyatt Regency suspended walkway collapse in Kansas City remind us of the tragedy, death, and incredible financial repercussions that can result from even the smallest mistake in analysis, design, and construction. Thus, within the engineering profession, both experienced and entry level engineers must have their work reviewed by another engineer. In fact, it takes a Professional Engineer licensed for the state in which the service is offered to sign and seal engineering drawings.

From 2007 - 2008, the author co-taught a course in Structural Analysis with Dr. Scott Hamilton, who authored papers explaining a learning technique he called Design Review.[4][5] After completing their individual homework assignments, students would conduct a peer review of the individual work, make comments on a form, and then make corrections to their work prior to turning it in for grade. The author observed both the good and not-so-good of that effort. Upon a return to teaching in 2016 following a change in military assignment and pursuit of a doctoral degree from 2009-2016, the author immediately observed students were busier than ever. The demands on the time of a West Point Cadet combined with the distractions of Generation Z led many students to turn in work with careless mistakes due to a rushed completion of the assignment. Many students were satisfied with simply turning in marginal work on time and receiving a "B" or "C" instead of achieving excellence and ensuring their work was error free.

The author, in a desire to improve student learning and instill professional behavior and habits in his students, implemented his version of Design Review in a Structural Analysis course during the Spring 2017 semester.[1] This iteration differed from previous iterations he participated in and reviewed in that:

1. Each review was worth 10% of a student's homework grade to motivate them to conduct a thorough review,
2. Each review team had to turn in a one-page memorandum summarizing the take-aways of their review,
3. A student had to select a different review partner for each assignment, and
4. A review team turned in their homework together as one team, cutting the instructors grading in half.

While not perfect, the students demonstrated through assessment and expressed via survey, that the Design Review learning technique improved both their grades and understanding of the material.[1] Convinced that it was a worthy endeavor, the author attempted another iteration during the Fall 2017 semester in a different course, The Design of Steel and Wood Structures.

2. Design Review Implementation

For most students in the course, the "hook" was already set, as students experienced the benefits of Design Review during their previous semester. However, for students new to Design Review, it was important to acquire buy-in. The author attempted to inspire students to give Design Review a try by appealing to their desires to soon join the engineering profession. Thus, some students were likely motivated through demonstration and explanation of engineer practices and the consequences of making mistakes. The author also understood there was a segment of the class whose sole motivation would be their final grade in the course. Seeing the effectiveness of this in the previous term, the author assigned 10% of each homework assignment to the quality of executing the Design Review.

Upon the completion of each homework assignment, a student would find another student to review their individual work prior to turning it in for grade. Each new assignment required each student to find a new partner. The intent of this requirement was to force students to communicate with their peers. Feedback from students in the previous iteration of Design Review was positive. Students consistently commented on how they enjoyed communicating with individuals they would not have otherwise met.

While reviewing another student's work, the reviewer filled out a Design Review sheet (see Fig 1). The author received a plethora of negative comments from students regarding the one-page memorandum requirement during the previous iteration. [1] Specifically, students thought it was redundant to the Design Review sheet they were already required to fill out. Thus, the author made slight modifications to the Design Review sheet to make it clearer and eliminated the requirement to also write a memorandum. The revised Design Review sheet required the reviewing student to annotate:

1. Is the work complete and easy to follow?
2. Do the answers make sense?
3. Does the work follow and apply the appropriate theory and methodology?

A "no" answer to any of the three questions required the reviewer to write out detailed comments as to why that was the case. Following the review, the reviewer would print and sign their name on the review sheet.

A student, after receiving a review, discussed points of contention with their reviewer and made a determination whether the suggested corrections were valid. Then, the

student annotated their opinion of the recommended changes on their Design Review form. While the previous iteration of Design Review required students to turn in their homework in pairs (or Design Review teams) for one grade, this iteration of Design Review required students to turn in their homework individually. In the previous term, students felt that a few of their partners would show up to a review without their work completed or without first giving a solid, individual effort. Students pointed out that their peer's poor effort was nonetheless rewarded with a higher grade than warranted because of their own personal work as reviewer.

DESIGN REVIEW REVIEWER COMMENTS:

Requirement 1: Truss Review

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

Do the answers make sense? YES ☐ NO ☐

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

If checked NO above, provide explanations:

REVIEWED BY:_____

(sign above printed name)

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DESIGN REVIEW ENGINEER COMMENTS:

Requirement 1: Truss Review

Fig 1. Design Review Sheet Example

3. Design Review Works!

3.1 Student Feedback

At the end of the fall semester, student feedback was collected in every course across the academy. All survey data collected was anonymous. All 48 students enrolled in the Design of Steel and Wood Structures completed the course survey. The author had access to all 48 of the student responses to Likert Scale questions (5 was strongly agree, 4 was agree, 3 was neutral, 2 was disagree, and 1 was strongly disagree) and freeform comments. For the university-wide question asking students if they were *responsible for their own learning*, students assessed this course higher (4.73 mean) when compared to others in the department (4.60 mean) and others across the academy (4.52 mean). The author noticed similar higher results when comparing questions such as *fellow students contributed to my learning* (4.54 mean versus means of 4.31 and 4.17 respectively), and *motivation to learn and continue learning increased* (4.375 mean versus means of 4.20 and 4.07 respectively).

While these differences are not solely attributed to Design Review, this cooperative learning technique made an impact. When specifically asked whether *Design Review helped increase their learning and knowledge of Steel Design by reviewing the work of their classmates and requiring them to explain their own work*, 36 students either agreed or strongly agreed, 8 were neutral, and 4 either disagreed or strongly disagreed (4.00 mean with a 0.98 standard deviation). Students were also asked if the *Design Review process corrected mistakes that both increased their grade and contributed to their learning*. Of the 48 responses, 44 students either agreed or strongly agreed (4.29 mean with a 0.68 standard deviation). These responses were in line with those from the previous iteration within Structural Analysis, which scored means of 4.1 and 4.6, respectively.

The specific changes made this iteration were also assessed within the survey. Students were asked if they felt *students in the class took advantage of Design Review by relying on their partner to get their homework done*. In the previous iteration, where design teams turned in their work together, the average mean was a 3.4. Students felt this iteration, where students had to turn in their individual work following the review, deterred students from taking advantage of their partners (2.42 mean with a 1.19 standard deviation). Freeform comments, a few of which are shown below, supported the numbers:

1. *It forced both people to complete their work accurately. Prior, some people would just depend on their partners to submit the work.*
2. *I like this format better because it ensures everyone put in effort to complete the assignment and doesn't rely on the other individual to do all of the work.*
3. *I liked it better because it allowed me to disagree with my partner and know that both would be graded. It also allowed for more individualized feedback.*
4. *I preferred this method because if you disagreed with your partner about how to do a specific problem, you could turn in different responses. Additionally, doing the individual problem set*

submissions forced people to complete their own work before meeting instead of coming to the meeting unprepared.

The elimination of the written memorandum requirement in conjunction with slight modifications to the Design Review form was another welcome change to the students. Students found increased efficiencies which led them to spend more time conducting a thorough review. A few of their comments follow:

1. *I preferred having the modified Design Review sheet as opposed to the memo. I actually got more out of having a detailed Design Review sheet instead of trying to just squeeze out a memo.*
2. *This was a major improvement. It allowed cadets to focus more on the actual work and processes and less on writing a memo.*
3. *So much better and far less stressful than last year. I spent more time actually discussing the work and fixing my mistakes rather than crafting a memo.*
4. *This was a benefit because it shortened the time required to complete the design review, which was a huge plus.*

3.2 Student Assessment

Goals of this iteration of Design Review included: reducing the number of mistakes made by students (improving grades), improving student learning, and creating an efficient cooperative mechanism for students to present their work. Design Review efficiency proved valid as time survey data collected from students showed an average of 83.5 minutes per student per lesson with the Design Review policy implemented. In the previous term without Design Review, students averaged 88.5 minutes per student per lesson (5 minutes more per lesson). More importantly, as indicated in student survey results, students clearly felt like their grades were improved due to the Design Review process. Validation of this sentiment was examined by comparing student achievement of course objectives. Specific portions of assignments and exams mapped to each of the five course objectives. Student performance was then compared to student performance from the year prior (without Design Review).[6] The assessment of student performance of course objectives was in accordance with the following criteria:

1 = Objective Not Met. Objective clearly not met, most (75%) of the students did not achieve it.
2 = Objective Marginally Met. Objective met by roughly half the students or minimally by most of them.
3 = Objective Satisfactorily Met. Objective clearly met by a solid majority (70%) of the students.
4 = Objective Solidly Met. Objective clearly met by the vast majority (90%) of students.
5 = Objective Clearly Met. All students have achieved the objective and can be expected to demonstrate it.

The definition of "meeting a course objective" was achieving a "C" level (70%) on the task. Comparison of student performance is shown in Figure 2. Students in the semester with Design Review either improved upon or matched the student level of performance of students that took the course without Design Review.

Course Objective	Assessment (Previous AT)	How Evaluated and Remarks
Design and analyze the members and connections of low-rise structural steel and wood structures using LRFD methodology, given a set of functional requirements and an architectural concept.	**5 (5)**	Overall course average 86.4% (previous year 85%). All students earned a combined average above 70%.
Describe the advantages and disadvantages of using structural steel and wood as building materials.	**5 (4)**	Averaging together PS1 and PS7 (Wood). All students earned a combined average above 70%. Previous year, 94% earned above 70%.
Describe and model the path of gravity and lateral loads through common structural systems.	**4 (4)**	Averaging EDP1, EDP2, and Structural Systems portion of WPR1. This year, 94% of students earned above a 70% (same as last year).
Use modern engineering software to analyze load effects and communicate structural plans in 2D and 3D.	**4 (3.5)**	Averaging together EDP and portions of PS scores. This year, 94% of students earned above a 70%. Last year 86% earned above a 70%.
Describe and predict structural stability concerns in members locally, in compression members, in flexural members, and in frames.	**4 (3.5)**	Averaging together specific PS, WPR 2, and TEE problems. This year, 94% of students earned above a 70%. Last year, 88% earned above a 70%.
Abbreviations: EDP – Engineering Design Problem, WPR – Written Partial Review (Test) , PS – Problem Set (Homework), TEE – Term End Exam		

Fig 2. Course Director Assessment of Course Objectives

4. Summary and Way Forward

Cooperative learning techniques are designed to encourage students to share the responsibility for their learning. By working with other students in pairs or in small groups, students can improve their mastery of the course content. As described by Joseph Lowman, "the [cooperative learning] technique involves much more than simply having students interact in class or help others with their work…there must also be a combination of positive interdependence…and individual accountability." [7]

As demonstrated through both student course end feedback and assessment of student performance, the cooperative learning tool Design Review proved valuable in improving student learning. In addition, it started developing the habit of getting engineering students in the practice of what engineers in practice already do (check each other's work). The cooperative learning requirement provided both an additional contact opportunity with the material and interactive experience where students explained their own work and observed how others presented their work. This reduced simple errors in homework, improved student grades, increased student learning, and developed student ability to communicate clearly and effectively. Observing these benefits, the author will continue to implement Design Review in the course going forward with the changes made this semester: eliminating the memorandum requirement and increasing individual accountability with individual homework submissions.

References

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