"Using Peer Design Review as an Undergraduate Engineering Education tool"

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Background

The ultimate goal of any teacher is to inspire their students toward lifelong learning. Many people, by nature, are accustomed to learning by doing. It is an active process. There are very few things people master by simply hearing or seeing only once. In fact, when considering the fundamental everyday tasks in life such as tying one's shoe, reading a book and driving a car, it is clear that each was mastered through practice. Just as world class athletes perfect their jump shot, split-fingered fastball or golf swing through practice, students become proficient through active learning and repetition. It is no surprise then, that within the engineering discipline, most successful instructors require their students to learn by doing. In fact, by definition, engineering is "the creative APPLICATION of scientific principles to design or develop structures…"[1]

The instructor may write or lecture in the classroom to convey ideas, but it's up to the student to apply the ideas in order to learn it. This active learning has proven to be a successful technique to foster student learning.[2]

A technique used recently within the Department of Civil and Mechanical Engineering (CME) at West Point is Design Review. Design Review is an active, cooperative learning technique where students check each others work prior to submitting the work for a final grade. In typical engineering courses, a student ideally reads the assignment prior to class, receives a lecture the next day, and completes a homework assignment. The Design Review adds to this traditional practice by requiring the student to also thoroughly review another cadet's assignment, discuss discrepancies with the cadet where there is disagreement, and then make corrections to their work prior to turning it in for grade to the instructor. The technique is designed to allow students to not only see the same material at least two additional times, but also generate out of class discussion of the subject with their classmates.

Within the scope of engineering, Design Review benefits the student by observing other ways of setting up and solving engineering problems. The diversity of learning styles and experience levels within a class lends itself to making Design Review effective. It motivates students to develop the ability to view problems from another's perspective, an important skill for engineers and any profession required to solve tough problems.

The peer pressure of having another classmate check their work should encourage students to organize their thoughts and produce a better product to avoid embarrassment. The interaction between peers causes one to become a classmate teacher and the other to be a classmate learner. Developing the skill and knowledge to coherently explain the material to a peer increases the level of learning by all involved. The superficial learning starts to disappear, and true material expertise begins to develop. This increase in motivation to learn and achieve can only lead to higher academic achievement. Assuming most students want to learn and are motivated by success in the classroom, the end result of Design Review should lead to an increase in morale and thus, and an increase and desire towards life-long learning.

Literature Review

Enhancing student learning by making them work with peers has shown to be effective through the research of several instructors. Alexander Astin's extensive study in *What Matters in College: Four Critical Years Revisited* included data from approximately 25,000 students at 159 college institutions during their freshman and senior years.[3] His research conveyed a persistent effect by peers on a student's development. In fact, Astin concludes, "the student's peer group is the single most potent source of influence on growth and development". What a student doesn't initially learn from reading their textbook, pick up during their 55 minutes of classroom instruction, or acquire as they work their way through a homework assignment can be learned from their peer during a design review. What is not understood by either member of the group then becomes an obvious gap in the material that can be addressed by the instructor.

Karl Smith tried a collaborative approach to engineering by putting his students in groups.[4] During class, the groups were given engineering problems to solve. Each group would put their solution on an overhead, and the instructor randomly selected individuals from each group to articulate their solution to the rest of their classmates. By randomly selecting the students, Smith attempted to keep all the students accountable for their understanding of the material. Through this and a myriad of other strategies, Smith revealed that students retained more information when seeing it more than one time and through a different method.[5] The active learning of group work caused the students to take greater ownership of their own learning. This led to an increase in class satisfaction and thus an increase in student learning.

The success of a peer teaching approach was witnessed first hand by the students at the University of California at Berkeley in a report from Uri Treisman.[6] Treisman started a Mathematics Workshop Program (MWP) after noticing the drastic differences in study habits between successful Chinese American students, who predominately worked in groups, and unsuccessful African American students, who typically worked by themselves. Treisman found through his research of 646 African American students over a ten year period that students involved in the collaborative MWP consistently achieved higher grades than those that chose not to participate in the program. The program provided a social setting for students to collaborate and solve supplementary problems with their peers. He found that students spent more time working on math when in the MWP (10-14 hours versus 6-8 hours), because students found the time was worth their effort. Seeing success in a difficult course motivated students to commit themselves towards academic achievement even more.

Observation of the collaborative Design Review technique by the authors took place the spring semester of 2007 in CE403, Structural Analysis. LTC Scott Hamilton, author of *Peer Review in Engineering Courses as a Learning Tool*, and MAJ Aaron Hill, coauthor of this paper, used Design Review as a tool in their course.[7] For every assignment throughout the semester, each cadet had to get two other cadets to review their work prior to 2200 hours the night before the assignment was due. This would give each cadet from 2200 hours until 1600 hours the next day to make corrections to their work prior to submission. Failure to complete the design review or submitting a bogus review would result in a 5% penalty. Unfortunately, the great idea of design review was not well-received by the majority of the cadets. Throughout the semester, it appeared as though reviews were just pencil whipped. Typical comments would be “Good job” or “Answer off a little probably due to rounding” on less than stellar work. Of the 45 responses in the course end survey to the question, "How did Design Review help you in learning course material", the overwhelming majority of the responses were extremely negative! Most cadets focused on the lack of sufficient incentive to do the review properly and time in their schedule to make the review effective.

Prior to this iteration, LTC Scott Hamilton tried three iterations of Design Review, which was met with some resistance by the cadets.[8] Nevertheless, Hamilton noticed an improvement in exam scores and an increase in the amount of documentation of assistance received from peers. Recommendations to improve the process included the need to sell the importance of the course material, the need to stress the importance of getting the right answers, and the need to clearly explain the expectations of the review. These lessons learned and the end-of-course survey comments from the cadets were taken, and Design Review was attempted by both authors in their respective courses, CE491: Advanced Structural Analysis, CE404: Design of Steel Structures, and CE403: Structural Analysis.

Design Review in CE491: Advanced Structural Analysis

In light of the student negativity towards what in theory is a promising technique to enhance student learning, Design Review was implemented with changes in term 08-1 in CE491: Advanced Structural Analysis. This course was known to be one of the more challenging electives with the major. Only those with a sincere desire to learn Structural Analysis typically signed up for the course. In addition, all of the students just completed CE403: Structural Analysis, where the negative responses with regards to Design Review were surveyed.

The big change to the previous policy used by Hamilton was a reduction in the number of reviews required from two to one. The hope was that by cutting the number of required reviews, students would commit the time previously devoted to two pencil-whipped useless reviews towards one high quality useful review. A second change was that students would be placed in formal groups of three to four students. The purpose of this change was to get students comfortable with each others' schedules and styles. With students responsible for selecting their own groups, the hope was to minimize extracurricular, living, and personality conflicts. A final change to accommodate the students' wishes was to eliminate the 2200 hours deadline to have their work reviewed. Cadets indicated in the CE403 end of course survey the previous semester the deadline kept quality reviews from occurring because they were not done working on their assignments by 2200 hours. While that in it self may be a sign that high quality effort is not being put forth by the student, it also does not leave room for extenuating circumstances that come up with the myriad of club squad, corps squad, and military requirements imposed on the cadets within the United States Military Academy (USMA).

Out of the 28 students in the course, 27 participated in an end-of-course survey identical to the one provided them in CE403 a semester earlier. Cadets were asked if the changes made to Design Review (changing two required reviews to one, having a designated group, eliminating the 2200 hour time requirement) made the design review process more valuable to cadets. On a 1-5 scale, the cadets responded with an average rating of 3.9. The cadets were again given an opportunity to provide freeform comments with regards to the review. Positive remarks included "the way it is set up now works quite well", "the changes made the Design Review more helpful…I caught a lot of my mistakes during the review", and "I liked the two changes from last semester." Five cadets pointed to making modifications similar to the way it was being done in CE404: Design of Steel Structures, by the coauthor, MAJ Steve Bert. Specifically, these cadets suggested turning in work on a due date, exchanging papers in class, and then having time to review the work before turning it in for a final grade. Another recurring comment existed with respect to the assignment of designated groups for the Design Review. Cadets commented that some would finish their work early and have to wait for the procrastinating students within their group to finish their work the night before it was due before they could get their work reviewed. It only took one procrastinator within a group to ruin it for other students in the group who managed their time wisely. The feedback indicated that adding the designated groups as a change may have contributed to the less than stellar score of 3.9 out of 5 for the changes made that semester.

The quality of the reviews throughout the 08-1 semester was about the same as the prior semester 07-2. Few conducted what would be considered a thorough review. Most of the obvious, major errors were found. Others simply indicated their answers didn't match, but that the process looked right. Bogus reviews or reviews that were not completed resulted in a 5% penalty, which ended up being five to eight points on most assignments. This didn't deter some students from seeing and treating the review as a nuisance. The 5% penalty was not stiff enough to really hold students accountable. Some were willing to give up 8 points in lieu of taking the extra time to have their work reviewed.

Somehow, students had to accept the fact that Design Review was important to them. During Lesson 2 of the course, cadets were told how Civil Engineers usually get only one chance to get the answer right because of the permanent nature of civil engineering projects. They were provided figures of how much time current engineering firms spend on design review and how the practice of punishing those who get it wrong dates back to Hammurabi. While it seemed to make sense Lesson 2, by Lesson 40, one expressed on their course end feedback that "it is the cadet's responsibility to ensure the best quality in his or her own work…if a cadet does not see this as important, I do not see how forcing by negative or positive incentives will make it more valuable for cadets in the future."

One noticeable improvement was in the student rebuttal with regards to the instructor grading of the reviews. It was clear that students knew what was expected of them. This was largely due to the fact that this was their second consecutive semester conducting Design Review. This is something to capitalize on during future iterations.

Design Review in CE404: Design of Steel Structures

Based on the comments from the CE403 survey conducted in 07-2, an alternate proposal was developed for Design Review in CE404. Based on the lessons learned by LTC Hamilton, it appeared that a design review procedure which is structured and provides adequate resources should result in an increase in understanding during the review process.[9] Proposed elements of structure and required resources are adequate time, a review tool such as a solution, accountability, and minimal distracters, such as sloppy writing or late submissions. In order to evaluate increased understanding two indicators, student self assessment and graded event performance, were selected.

Two assignments that students historically struggled with were selected as Design Review assignments. There was one main difference between this Design Review procedure and the one used in CE403. In this CE404 design review, students did not have an opportunity to make changes to their work following the peer design review. Following each design review, students were given a survey to assess the effectiveness of the review process and resources provided. The survey also assessed how effective the Design Review was at increasing understanding.

In the first assignment, the quality of the review was worth 30 points out of a 120 point assignment. MathCAD was required for the solution in order to minimize effects of sloppy hand writing. Also, an instructor solution was made available for the review process. Students completed the assignment and turned it in during class for accountability. The assignment was immediately and randomly re-distributed to the students for purposes of a review which would be due at the beginning of the next lesson. The reviewers were to identify errors and make comments. The quality of the review was graded based on how the reviewer's evaluation compared to the instructors. Upon completion of the review process an anonymous survey was conducted using the Blackboard Survey tool. The survey questions are listed below.

1. I did well on PS4 part 2 (Girder Analysis).
2. The problem that I REVIEWED was organized and easy to follow.
3. Based on my level of understanding and the cut sheet provided, the work I REVIEWED was done correctly.
4. My understanding of Girder Analysis INCREASED after reviewing someone else's work.

5. What recommendations would you make to the review process, in order to make it a more useful tool in developing YOUR understanding.
6. Which of the following do you believe is the best use of the review process.
    a. Use for all problems, giving credit for quality of the review.
    b. Use only for historically difficult problems, giving credit for quality of the review.
    c. Use for all problems, but instead of being graded on the review, as was done on PS2, return the reviewed problem set and allow the corrections to be made prior to final submission.
    d. Use for historically difficult problems, but instead of being graded on the review, as was done on PS2, return the reviewed problem set and allow the corrections to be made prior to final submission.
7. Which tool would you prefer to have available for your review.
    a. Instructor Solution
    b. A "Cut" sheet of typical problem areas for this type problem
    c. Intermediate values
    d. None. Use my own solution.

Table 4.1a Results of questions 1-4 from the first CE404 Survey

Question	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
I did well…	6%	41%	27%	18%	8%
…Organized and easy to follow…	18%	53%	12%	12%	4%
…done correctly.	6%	55%	18%	14%	6%
My understanding	8%	41%	29%	16%	6%

increased…					

Table 4.1b Results of question 7 from the first CE404 Survey

Intermediate Values	Solution	Cut Sheet (no values)	None
18%	47%	33%	2%

During the second iteration of Design Review, the solution was not required to be in MathCAD. In addition, although a solution was the most preferred tool available for review at 47% of the respondents, I wanted to compare another option. I decided to combine tools. A cut sheet listing critical steps and their intermediate values was provided for the review. The assignment was turned in for accountability and immediately re-distributed for review and final turn in the following lesson as was done during the first review. Only 20 out of 120 points were allotted to the quality of the review. The survey questions were unchanged from the first survey so that a direct comparison could be made. Results of the survey from the second design review are provided in tables 4.2a and 4.2b.

Table 4.2a Results of questions 1-4 from the second CE404 Survey

Question	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
I did well…	5%	51%	22%	20%	2%
…Organized and easy to follow…	16%	65%	5%	9%	4%
…done correctly.	11%	49%	16%	22%	2%
My understanding	13%	51%	20%	16%	0%

increased…					

Table 4.2b Results of question 7.

Cut Sheet with Intermediate Values	Cut Sheet (no values)	Solution	None
58%	13%	27%	2%

A cross-question comparison between question 1 and 4 was made to see if those who tended do poorly on the assignment were more likely to reap a benefit from the design review. The data only includes results from the second survey due to a data sorting error that made this type of analysis impossible to re-create.

Table 4.3 Results of cross question comparison

Question #1/Question #4	Understanding Increased, Agree and Strongly Agree (35)	Understanding Increased, Disagree and Strongly Disagree (9)
I did well, Agree and Strongly Agree	20/35 (57%)	6/9 (67%)
I did well, Disagree and Neither Agree nor Disagree	15/35 (43%)	3/9 (33%)

There appears to be a correlation that those who do poorly are more likely to increase their understanding 15 of 18, which is expected, but it also shows that even those who do well receive some benefit in increased understanding. Based on the comparison above, 20 of 26 of those who did "well" realized an increase in understanding. This would indicate that peer review is a beneficial practice for all students and warrants further refinement. Of the three who did poorly and failed to increase understanding, two reviewed work that was either unorganized and/or not done correctly. In addition, 31 of 35 who increased understanding thought the work was organized and easy to follow. The quality of work in terms of organization appears to be about the same for the assignment that was required to be done in MathCAD and the one that could be done in any format. The data is not statistically significant, but warrants consideration in a formal review procedure.

In the second review students were given key values. Poor students identified errors in values, but they were unable to ID what went wrong and in some cases just said "close enough." Returning the work to a student for corrections may not fix this as the poor student may assume it was just round off and not make any adjustments. Overall, poor students are only able to spot differences between student work and the solution. It may be more educational to have poor students review good students work since the good students will be more capable of going back to find the errors.

In the first problem set review, I had several better "A" student's review work. Although they were able to catch many mistakes, they tended to make incorrect comments such as marking a length wrong that was actually correct. Without a solution or guide, they were also less likely to ID major problems that resulted in major point cuts. This makes a strong case for providing reviewers with a tool to aid in the review process. Simply relying on there own work may lead to reinforcing their own errors and/or confusing the person being reviewed.

As expected, the level of detail in the reviewer comments varied. However, good students were slightly more consistent at identifying the errors. Reviews from the first

Design Review tended to be more detailed due to the provision of a full solution as compared to the second review where only a cut sheet was provided. Although the reviewers identified errors, they did not identify root causes. No guidance was given to do this so it makes sense based on the “law of least work.” Although further study should be conducted, this may indicate that allowing students to make corrections after the Design Review will only lead to a slight increase in grade averages as many students will struggle with identifying root causes. However, the identification of errors should enable major shortcomings (i.e. forgetting to check the strength of the beam and encourage students to complete all work). The affect on grades should be a tighter curve with a higher low score. The benefit of getting all students to just “do” the entire problem should payoff in better understanding of how to solve the problem. An assessment of the criteria used to develop the CE404 design review procedure with recommendations is given below.

Key elements of structure and required resources:

1. Adequate time for review: Only 1/104 total responses included a negative comment on available time. Recommend sustaining the current timeline. Turn in problem at beginning of lesson, redistribute then review and submit the next lesson.
2. Review tool (i.e. solution): A cut sheet with intermediate values is the preferred tool according to the student responses.
3. Accountability (grade for review): It is difficult to determine what is necessary to encourage a given group. The points for review decreased from 30 to 20 between the two reviews. There was little noticeable difference in the quality of the

review. The results of question 6 favoring credit for “quality of the review” ranged from 57% in survey one to 38% in survey two. If a group internalizes peer review as a value, then accountability may not be an issue. I believe this would vary from group to group and a set rule or recommendations is not justified.

4. Minimize distracters (i.e. sloppy hand writing, not turning in on time) Does not appear to be an issue. Recommend using MathCAD solutions to be safe.

Assessment of indicators showing increased understanding:

1. Student Self Assessment: Poor students reviewing good work were able to realize something they didn’t understand while completing their own work, as explained by their own grading comments i.e.

   “Thanks, I had no clue how to do this now I kind of do.”

   -From a D-student comment after reviewing an A students work

   The student opinion ranged from 49% for the first review to 64% for the second review, of the students agreed or strongly agreed that the Design review increased their understanding of the material.

2. Graded event performance: Using the WPR results between earlier years where peer review was not used and the results from 08-1 where design review was used did not result in a conclusive relationship. Possible forms of error such as differences in problem difficulty level and non-uniform point cuts between years may have been contributors to the inconsistency. Results of the comparison are listed below.

a. Tension Splice Question (first design review) Avg on WPR1 08-1=80%; 07-1=82%
b. Girder Question (second design review) Avg on WPR2 08-1=86%; 07-1=65%
c. TEE 06-1 Avg Beam/Girder 88.8%; Tension 84.7%; Incoming QPA 3.16
d. TEE 08-1 Avg Girder 90.2%; Tension 80.5%; Incoming QPA 3.09

Other Considerations:

Cadets overwhelmingly believe that the use of peer review should not be required for all problem sets. My belief is that they view the review as a trite check the block hurdle if it is a routine requirement. This is also indicated in the negative responses of other course surveys regarding the use of peer review. Peer review should therefore be reserved for the more difficult subjects in order to obtain a greater emphasis. The student perception of the most effective review process is split between evaluating the quality of the review or in allowing corrections following the review. The method used may be more a function of instructor preference or available time. A comparison is made below:

Instructor Evaluated Peer Review:

- Advantage-Establishes accountability of the reviewers' performance.
- Disadvantage- Student isn't rewarded for understanding and correcting their own errors.

Allow corrections based on peer review, prior to final submission:

- Advantage- Student is rewarded for understanding and correcting their own errors. A third exposure to the problem. No additional grading effort, grading may be easier due to more correct solutions.
- Disadvantage-Reviewers are not held accountable. Would require additional time to allow corrections. Likely to result in higher grades with less distribution.

Design Review in CE403: Structural Analysis

Another attempt at fine-tuning Design Review was done in Structural Analysis in term 08-2. This was the first time they were participating in this collaborative technique. Learning from previous iterations, the importance of Design Review was emphasized. A relevant and recent real world incident brought relevance to the students in the collapse of the I35 Bridge. To highlight the incident, excerpts from the National Transportation Safety Board report were attached to the blackboard: "the investigation has determined that some of the gusset plates were undersized…the review process in place at the time of the design failed to detect the error…beyond the designer's internal review, there does not appear to be a process in place to identify original design errors in bridges…gusset plate design calculations are not usually reviewed during major modifications on bridges."[10] Under the National Transportation Safety Board report on the board is written, "THIS IS WHY WE DO DESIGN REVIEW!"

Examples of good and poor design review comments were discussed Lesson 2 and reviewed again Lesson 5 in order to ensure cadets didn't waste time figuring out the right way to annotate their review. Reviews would only be done on select assignments deemed of significant importance by the instructor, and a heavy incentive of 20 points for a 100 point assignment would be set aside for the review. The hope was that 20 points would hold students more accountable for their review effort.

The feedback from this iteration was much more positive in comparison to the year prior in the same course. The following five questions were asked in a mid-semester check on student feedback on an opinion scale:

(1) I did well on problems where I participated in the Design Review Process in accordance with its guidelines (i.e. all work completed prior to review and made changes to reviewed work).

(2) My understanding of the material increased after reviewing someone else's work.

(3) The problems that I reviewed were organized and easy to follow.

(4) The problems that I submitted to the reviewer were organized and easy to follow.

(5) My grade increased due to participating in the Design Review Process.

Question	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
(1) I did well…	18.2%	57.6%	18.2%	6.1%	0%
(2) My understanding increased…	27.3%	42.4%	21.2%	9.1%	0%
(3) The problems I reviewed were organized…	6.1%	66.7%	18.2%	9.1%	0%
(4) The problems I submitted were organized…	15.2%	42.4%	33.3%	6.1%	0%
(5) My grade increased…	30.3%	39.4%	18.2%	12.1%	0%

Over 70% of the 40 students surveyed believed they not only did well on the assignments that were reviewed, but also saw their grade increase as a result. More importantly, almost 70% also attribute a higher level of understanding due to the Design Review process. Results from their exam grades also proved a higher level of understanding. The grades for the first exam following this iteration of Design Review were outstanding, with a course average of 91.11%, no failures, and 35% of the course receiving an A+. These scores were an improvement from the course scores one year prior during an earlier iteration of Design Review, where the average was 90.68% with one failure, and 22.81% of the course earning an A+. Regardless, it is important to note that both groups of students clearly performed well while using some version of Design Review. This latest version just may have helped more of the students buy into the program.

A correlation also exists with respect to student performance and conformity to the Design Review process. The table below shows a comparison between exam performance and Design Review grades and course performance and Design Review grades. With the exception of the one student with a D in the course who managed to do well on the Design Reviews, there is a consistent trend showing those that perform a higher quality design review perform at a higher level on exams and in the course as a whole.

EXAM GRADE	DESIGN REVIEW AVERAGE
A	95.26%
B	93.56%
C	86.25%
D	82.5%

COURSE GRADE	DESIGN REVIEW AVERAGE
A	97.86%
B	93.55%
C	86.07%
D	90%

Student freeform comments were also significantly more positive than in previous iterations. One cadet pointed out, “it encouraged some discussion of the material, and talking through the logic made things more clear.” Others noted, “everyone has a different perspective…and to see it through someone else’s work helps to solidify concepts that may otherwise be hazy.” Another noted the added peer pressure helped them, “it really makes me work with other people and do my problem set early. I normally just work by myself and if I get stuck then oh well. But the Design Review makes me put work down…”

Furthermore, the overall quality of the reviews increased twofold! Not only were mistakes in major concepts being corrected, but what assumptions to make on problems and which coefficient to use from a table where being discussed. On multiple occasions, students wouldn’t be able to resolve their differences and actually picked up the phone to have the instructor break the tie! This is the kind of energy and effort that lead to lifelong learning.

After several attempts at refining the design review, the following recommendations may be helpful in the establishment of a design review process in other courses.

1. Explain the goals and standards of the design review. Provide examples of good and poor review comments.
2. Limit the number of reviewed events.
3. Control the exchange of work. Do not put the burden on the student to obtain the work that they are required to review.
4. Provide a substantial reward mechanism, such as 20% of the event grade and/or allow corrections to be made.

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[1] *The Engineers' Council for Professional Development.* Science, 1941. Volume 94, p. 456.

[2] Bonwell, C.C. and J.A. Eison, *Active Learning: Creating Excitement in the Classroom.* ASHE-ERIC Higher Education Report No. 1, George Washington University, 1991.

[3] Astin, A. W. *What matters in college: Four critical years revisited*. San Francisco: Jossey-Bass Publishers, 1993.

[4] Davis, B. G. *Tools for Teaching*. Jossey-Bass Publishers: San Francisco, 1993.

[5] Smith, K. A. *Inquiry-based Collaborative Learning*. University of Minnesota, 1993.

[6] Fullilove, R.E., & Treisman, E.M. (1990). Mathematics achievement among African American undergraduates at the University of California, Berkeley: An evaluation of the mathematics workshop. *Journal of Negro Education*, *59*(3), 463-478.

[7] Hamilton, S. *Peer Review in Engineering Courses as a Learning Tool*.

[8] Hamilton.

[9] Hamilton.

[10] National Transportation Safety Board Safety Recommendation H-08-1, 2008.