Longitudinal Study of Online Statics Homework as a Method to Improve Learning

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Abstract

Background – Score improvements and retention are important metrics in studying the efficacy of any learning intervention. Research studies have shown a positive correlation between time spent completing online homework assignments and student performance on final exams. Yet these studies are not only rare in the field of engineering; they are generally not longitudinal in nature.

Method –This study design was three-fold. Firstly, it employed a quasi-experimental study using an online homework system, *MasteringEngineering,* in the statics course. Students were compared in two statics courses. In one course students submitted written homework and in the other course students worked and submitted homework problems online. Students received the same final exam, making direct comparisons feasible. Secondly, data were gathered from a traditional mechanics of material course where no online homework system was employed. Again, the same final exam was given for direct comparison. Thirdly, a concept analysis was run using Concept Assessment Tool for Statics (Steif, 2010).

Results – Students who used the online system showed an improvement of 0.7 (± 0.2) in effect size on the final exam when compared to written homework. Students who used the online system scored 79% (*SD*= 8%; *N*= 69) on average on the final exam. In comparison, students prepared via written homework scored 70% (*SD*= 16%; *N*= 64) on average on the same final exam. These results held for the subsequent mechanics course where students previously prepared via online

statics homework scored 79% (*SD*= 8%; *N*= 66), and students prepared via written homework scored 63% (*SD*= 18%; *N*= 79) on the same final. Furthermore, an independent instructor taught the mechanics course from the statics course, removing potential bias. Results were statistically significant. Independent of the historical analysis, another analysis was run on students in the online homework statics course. Students were given pre / post tests to measure understanding on nine concepts, with friction being the only topic yielding an inadequate learning gain (difficulty change of friction 0.04 ±0.28). In conclusion, the online homework intervention showed an improvement of 0.7 effect size when all other elements in the course remained unchanged.

I. Background

Research studies have generally shown a positive correlation between time spent completing homework assignments and student performance. For example, Paschal et al. (1984) found a positive effect of homework on achievement in their review of 15 studies on the subject; Cooper (1989) found positive effects in 14 of the 20 studies (70%) they reviewed. Cooper (1989) also found evidence that students who spend more time on homework received better grades in 43 of the 50 reviewed studies (86%). Keith (1982) showed that, among high school students, those with low ability were able to achieve grades commensurate with students of higher ability if they did one to three hours of homework per week.

The importance of feedback and grade-dependence on homework has also been shown. Trussell and Dietz (2003) showed that test performance for electrical engineers was better for students whose homework was graded than for those whose homework was not graded (a repeated experiment did not show a statistical difference). Paschal et al. (1984) concluded that the positive effects of homework were enhanced when it was graded and also when comments were written on the assignment.

The idea of web-based homework is not new, and several studies have reported some advantages to this type of learning. Flori et al. (2002) showed that students who used web-based homework for engineering dynamics scored better on exams than those who did not. Taraban et al. (2005) found that the use of online thermodynamics homework did not require excessive time from the students, resulted in improved test scores, and that the immediate feedback from the system was the primary reason that it was such an effective learning tool. Compared to traditional paper-and-pencil assignments, Dufresne et al. (2002) found that web-based physics homework resulted in test scores that were approximately one-third of a standard deviation higher than previously. They also concluded that immediate feedback was an important element for the effectiveness of web-based homework, in addition to their observation that students spent more time on the web-based homework.

These published studies support the hypotheses to be verified by this study: making students accountable via graded homework improves students' test scores, using an online homework program equipped with randomizable variables deepens the students' understanding of material, and aligning homework requirements to course goals results in improvement of long-term retention and better performance on the mechanics of materials and engineering mechanics sections of the FE exam.

II. Purpose

In order for students to master the concepts and material covered in statics, it is imperative that they solve a large number of problems. An important goal of any statics course is to engrain good problem-solving techniques into students to prepare them for future courses, particularly, in mechanics of materials and dynamics courses. Encouraging students to spend the requisite amount of time working on statics homework outside of class was challenging. This study investigated if an online homework system, when implemented with instructor oversight, could increase student performance in the current statics course and beyond.

As a gateway course, statics covers basic engineering concepts; it is a critical component in preparing students for future courses, with the ultimate goal of passing the Fundamentals of Engineering (FE) exam. The FE is a national standardized test that engineering students are required to take. They take the first part during the final year of their undergraduate work; they take the second part after completing four years of on-the-job experience. Students' performance at Colorado School of Mines has been at about 9% above the national level over the last seven offerings of the exam. An important university goal is to maintain and improve student performance on this key measure.

Prior to introducing the online homework management system, the written homework was assigned on each class day, as has been the custom for over 30 years at Colorado School of Mines. The assigned written homework was collected on the next class day and graded by student graders. Due to large class sizes, thorough grading of written homework was compromised. Furthermore, many of the statics students seemed to have access to the textbook publisher's solution manual. As a result, we noticed widespread copying on paper homework. We had tried to assign bonus problem sets for extra credit that were optional to improve exam performance and retention of concepts. The bonus problems were selected from alternative sources to which the students did not have access. Alternatively, we also tried to assign class projects, which included computational software to plot the results over a range of a variable with a goal of improved learning and long-term retention of fundamental concepts. The students were asked to interpret the plots and present the results in a formal report. Both alternative methods to paper homework had limited success due to students copying the reports from each other.

Thus, we looked for another solution to encourage students to engage more with the statics material outside of class. An online homework management system equipped with randomized variables developed by a textbook publisher was used in 2009 to see if we could encourage students to practice more outside of the classroom. Furthermore, the newness of the program meant that the unique problem sets were not yet spoilt with answers published elsewhere. The improvement in exam scores was remarkable. Early data from subsequent courses also looked promising. We are hopeful that we should also see a better performance on the Mechanics of Materials and Engineering Mechanics sections of the FE exam.

The goals of this study were to demonstrate that regular and intensive online statics homework assignments centered on problem solving would measurably improve test scores and the students' understanding of the statics course material, and improve understanding of key concepts while students were enrolled in the follow up mechanics of materials course. A follow up study is proposed to see if there are any improvements in FE scores on its statics and mechanics of materials problems. We have plans to track the students from this 2009 study to the final completion of the FE.

III. Methodology

The quasi-experimental design (Shadish et al., 2002) was used to explore the effectiveness of an online homework and tutoring system for the statics course from 2008 to 2009 academic years. In addition, a similar analysis was conducted on the follow up course for mechanics of materials (mechanics) to determine retention of the statics material. Hibbeler's textbook, *Engineering Mechanics: Statics,* and its accompanying online tutorial and homework system was used to assign all homework problems to students in the fall 2009 semester of statics. *MasteringEngineering*™ is built upon the same system as *MasteringPhysics*™ (formally, "myCyberTutor"), an online physics homework system for which research has been done showing that it improves student learning (Morote & Pritchard, 2009; Warnakulasooriya et al., 2007).

MasteringEngineering is an instructor-managed homework and tutorial system. It is designed to provide students with customized coaching and individualized feedback, as they are working the problem, to help improve problem-solving skills. The students receive specific feedback on common errors when a particular answer is incorrect. Hints provide individualized coaching to students and can be skipped when they are not needed. This system has the capability to draw free-body diagrams, write equations, and accept specific answers. It coaches students on problem-solving techniques by asking them to solve simpler sub-questions as they work toward a final answer. (See Figure 1.) Furthermore, the instructor is enabled to incorporate customized problems into the course with automated grading. The grade book identifies students that are having difficulty and shows challenging areas for the students. The grading system can identify the most difficult problem, the class grade distribution, and how much time students are spending on problems. Because each student is assigned unique problem input values by the program, cheating and copying are greatly reduced, if not eliminated altogether.

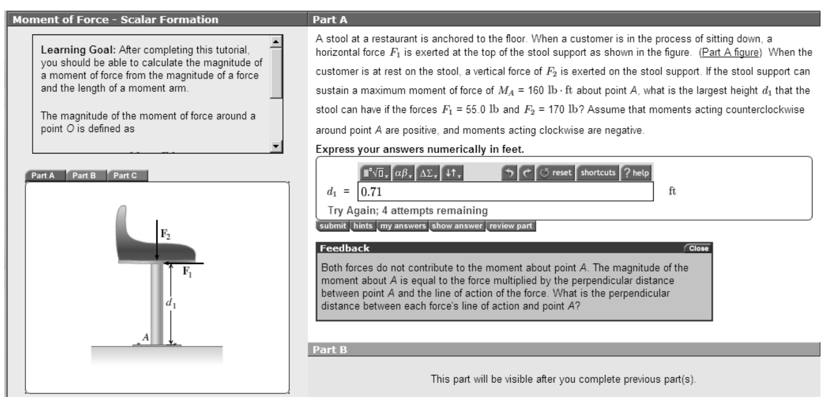

Figure 1. Sample problem from *MasteringEngineering*.

We compared data from 2008 and 2009. There were no other changes in the course: instructor, course goals, and weekly quizzes remained the same. As mentioned previously, prior to 2009, two Teaching Assistants (TAs) graded homework assigned from a different publisher's textbook. Fortunately, the same TAs, who hand graded the final exams, were available for both years. The same final exam was administered at the close of the course. Primarily, the homework items came from Hibbeler's end-of-section problems with the randomization feature set on to prevent sharing of answers. Three short assignments (three problems each) were administered every Monday, Wednesday, and Friday. The items were selected by the instructor to be short, targeted assignments to keep the students focused. The items were aligned to the weekly in-class quizzes. All 2009 students were required to use the online system; they were not informed in advance that homework would be delivered in this new format.

First, we compared results between the statics courses of 2008 and 2009. Test scores for the students enrolled in statics for the fall semester of 2009 class were compared to test scores for statics students from fall semester 2008 and they demonstrated marked improvement. It was possible to give the same final exam in Fall 09 and Fall 08 because this test is never returned to the students.

Next, we looked at the subsequent course, mechanics of materials, and compared student test scores on its first exam 1. We compared exam results of spring semester 2010 students who were in the statics treatment group to students from the previous spring semester from 2008 and we saw an improvement. It is reasonable to infer that the students in the treatment group demonstrated a better understanding of statics in 2009; and that they also retained this knowledge as demonstrated on the first exam of the mechanics of materials course.

While this study did not probe student motivation or other qualitative data, there was an opportunity for students to give their opinion on the online program once they were enrolled in the subsequent mechanics course. Students in the mechanics course completed an anonymous survey, which asked them if they liked using online homework the previous semester in their statics course. Out of the 51 students who took the survey, 18 said that they liked it; 19 said that they kind of liked it; and 9 didn't like it. (The remaining 5 students took statics in a prior year; hence, they had no experience with the program.) This was an interesting result for the instructor of the statics course. He had anecdotal evidence that the majority of his students revolted against using online homework at the start of the course. It was only by the end of the term that student opinion changed (as shown by the survey data), most likely because students only saw the benefit of sweating through their homework at test time.

Furthermore, we had the opportunity to add one more analysis based on a nationally recognized conceptual exam in statics. Results of the concept level analysis are included in this study. These results shed more light on the students' understanding in this particular 2009 statics course by observing how difficulty levels for nine concepts were changed from the pre- to post-tests. Statics is a pivotal class for engineering students and students must have a good understanding of the basic concepts in order to be successful in the classes for which it is a pre-requisite and on the FE exam. The "Concept Inventory" approach (developed by Frontiers in Education) was used to eliminate misconceptions in statics. The Concept Assessment Tool for Statics (CATS) was used to test concepts and misconceptions in the Statics classes. CATS can be viewed at http://engineering-education.com/CATS/intro.htm.

IV. Results

To begin, it was assumed that the students' knowledge levels before the statics courses began were about the same. Since all the students in engineering majors at Colorado School of Mines are expected to follow similar career paths, and since the SAT scores of the students in each statics course were similar enough in 2008 and 2009, it can be assumed that both statics courses in 2008 and 2009 had similar levels of students. Under this assumption, one of the statics courses in 2008 was selected as the course taught in a traditional way (i.e., assigned paper and pencil homework assignments), and one of the statics courses in 2009 was selected to be taught using an online homework system, *MaseringEngineering*, as a supplementary tool for the course. The performance differences between these two groups were compared.

Mechanics courses are more advanced courses taken after the statics courses. Two courses were chosen for comparison in this follow-up study. One was a mechanics course from fall 2009 where the students had paper homework and were taught in a traditional course setting in their prior statics course. The other was a mechanics course from spring 2010 where the students were also taught in a traditional classroom setting but had used an online homework system in their prior statics course. The students in these two mechanics courses (fall 2009 vs. spring 2010) were each prepared by two different statics instructors. Any factor that might cause the variability among the students from the different statics course instructors exists in both groups of the mechanics courses (paper vs. online homework).

The midterm and the final tests were administered for the statics courses and the mechanics courses. The test scores were collected to measure how the students' performances improved and to explain how much the students learned during the semesters. The final exam administered for the statics course in 2008 (paper) was exactly the same as the one given in 2009 (online), and the final exams for the two mechanics courses were the same. So a direct comparison between the statics final scores in 2008 and the scores in 2009 and the comparison between the mechanics final scores in fall 2009 and the ones in spring 2010 could be used as one of the indicators of the effectiveness of using a gradable online program in the statics courses.

Paper homework vs. online homework in the statics courses

There were 64 students who took the engineering course in 2008 completing paper homework assignments compared to 69 students who took the same course in 2009 using an online homework system. For the group in 2008, the mean scores (in percentages) of midterm and final exams were 71.55 (*SD* = 10.96) and 70.32 (*SD* = 16.13), respectively. In general, the mean scores for the group in 2009 were higher compared to 2008. The mean scores were 81.31 (*SD* = 8.65) for midterm and 78.58 (*SD* = 8.27) for the final exam (see Table 1). Figure 2 also presents that exam scores without an online system are lower than the ones with the online system.

Table 1. Descriptive statistics of each exam in both academic years (2008 and 2009).

Paper Homework (2008)							
Test	N*	Mean	SD	Median	Min	Max	SE**
midterm	51	71.55	10.96	74.67	36.33	87.33	1.53
final	51	70.32	16.13	72.31	30	100	2.26
Online Homework (2009)							
Test	N	Mean	SD	Median	Min	Max	SE
midterm	59	81.31	8.65	81	63.67	99	1.14
final	59	78.58	8.27	77.69	61.54	96.15	1.08

*51 students out of 64 students (total number of students registered for the course) took the midterm and final exams in 2008. For the course in 2009 (with 69 students), 59 students took the midterm and final exams.
**SE: Standard Errors

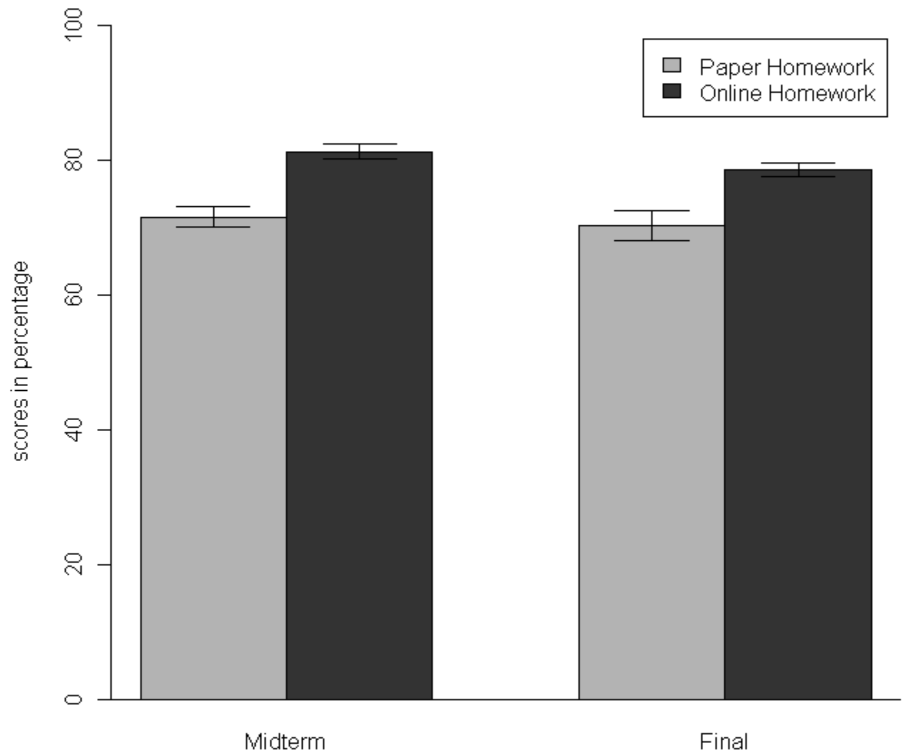

Figure 2. The mean scores of each exam with standard errors in academic years of 2008 (Paper Homework) and 2009 (Online Homework) for the Statics course.

Two independent groups of students in 2008 and 2009 with assumed same knowledge levels were compared based on their test scores. For each group, two different types of tests were given to measure the students' performance on the statics course. The two independent groups from two different academic years were treated as the between-subjects effect to test the effectiveness of using an online homework system. The first group (in 2008) did not use an online homework system, but were given paper homework assignments; whereas the other group (in 2009) used the online homework system. The two different test scores within each group were regarded as the within-subjects effect to test if there was any significant difference between the two different tests. Because of the characteristics of the data in which there are both between-subjects effect and within-subjects effect, the 2×2 mixed-design (split-plot) ANOVA was used to analyze the data.

The interaction effect between the test type (midterm and final) and the group effect (paper homework vs. online homework) was also tested in the model. The ANOVA analysis shows the results from the mixed design analysis. There was a significant difference between the two groups in 2008 (paper homework) and 2009 (online homework), $F(1, 108) = 20.875$, $p < .0001$, meaning that the overall test scores in the group using paper homework were significantly lower than the ones in the group using an online system with randomizable variables. The significant overall difference among the two different tests (midterm and final exams), regardless of which group the students belong to, was found, $F(1, 108) = 5.481$, $p < .05$.

Another type of analysis used to compare the two groups was found to be consistent with the ANOVA analysis reported above. The two types of effect size values were computed as a measure of distance between the two different distributions: the distance between midterm in 2008 (paper homework) and midterm in 2009 (online homework), the distance between final in 2008 and final in 2009, and the distance between pre and post in 2009. This measure of distance can be regarded as a measure of the difference between two different distributions where the high effect size value indicates a big difference between the distributions. For Cohen's d, an effect size of 0.2 to 0.3 is considered as a small effect, about 0.5 as a medium effect, and 0.8 to infinity as a large effect (Table 2; Figure 3).

Table 2. Two types of effect size values with standard errors for each test.

	Midterm	Final	Pre/Post
Effect Size	1.006	0.665	1.210
SE*	0.161	0.200	0.214

*SE: Standard Errors

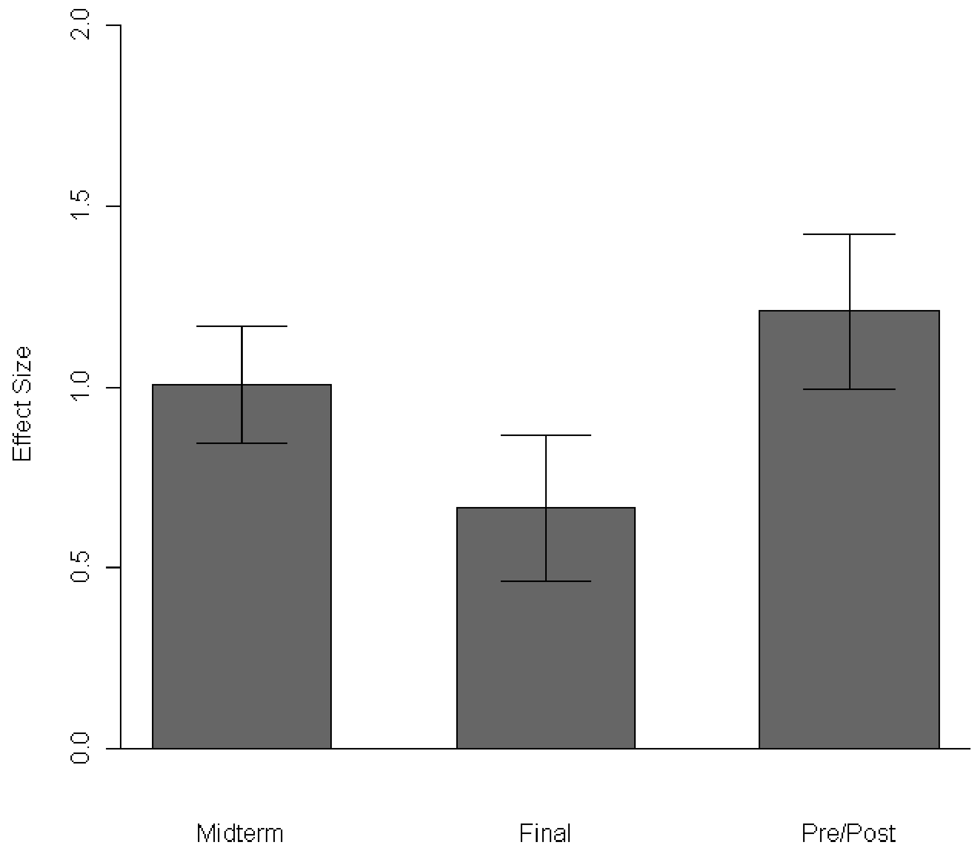

Figure 3. The values of Effect Size with standard errors for each test between Paper Homework and Online Homework for the Statics course. The positive value of Effect Size indicates the improvement affected by using an online homework system. The effect size of 0 means that there is no difference between Paper Homework and Online Homework, that is, no positive effect of using the online homework system.

Longitudinal study with the mechanics courses

This longitudinal study was interested in determining student retention in the follow up course. Would students prepared with an online system do better than students prepared with paper homework in the subsequent mechanics course? There were 79 students who took the following mechanics course in fall 2009 having been prepared via paper homework assignments in their statics course. They were compared against 66 students in the spring 2010 mechanics course who had been previously prepared with an online homework system in statics. For the group prepared by paper homework in fall 2009, the mean scores (in percentages) of midterm and final exams were 75 (*SD* = 13.54) and 62.74 (*SD* = 17.74), respectively. The mean scores for spring 2010 (prepared with an online homework system) were 78.84 (*SD* = 15.97) for midterm and 78.58 (*SD* = 8.27) for the final exam (see Table 3). Figure 4 illustrates the mean scores for the midterm and the final exams in 2009 (paper homework in grey) and 2010 (online homework in black). The final mean score in 2009 was shown to be significantly lower than the one in 2010 and also compared to the midterm mean scores in both 2009 and 2010.

Table 3. Descriptive statistics of each exam in Fall 2009 and Spring 2010.

Paper Homework (2009)							
Test	N	Mean	SD	Median	Min	Max	SE
midterm	79	75	13.54	79	37.3	96	1.52
final	78	62.74	17.74	65	17	100	2.01
Online Homework (2010)							
Test	N	Mean	SD	Median	Min	Max	SE
midterm	66	78.84	15.97	83.5	21	99	1.97
final	59	78.58	8.27	77.7	61.5	96.2	1.08

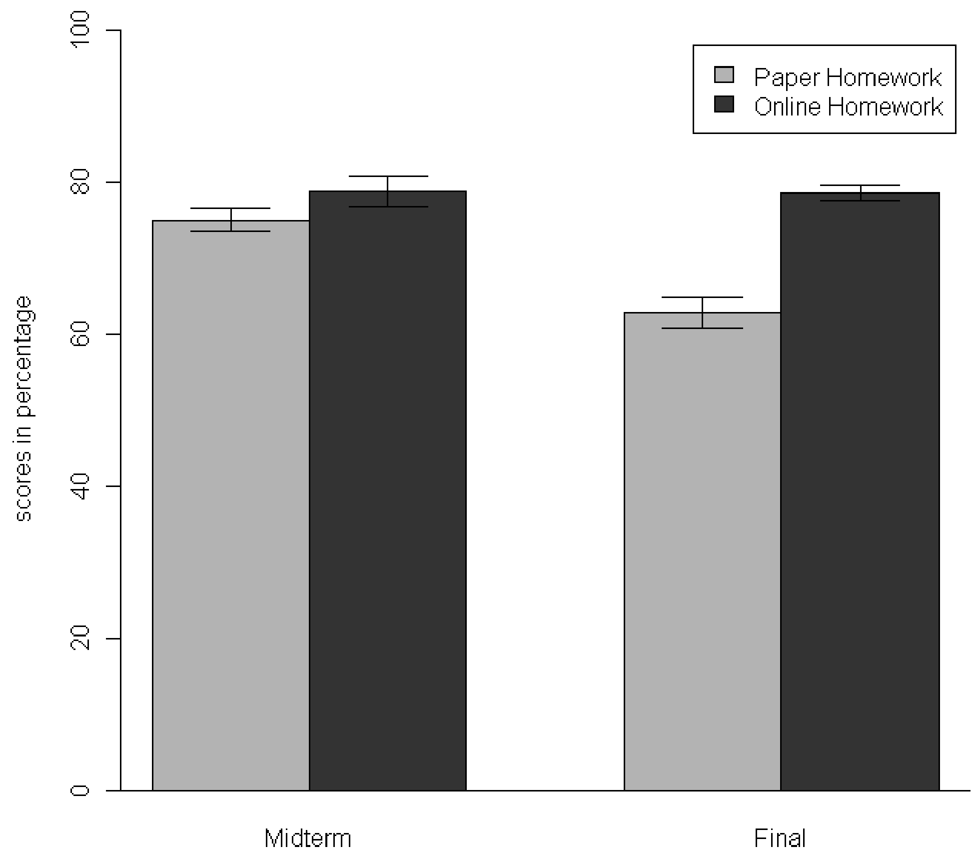

Figure 4. The mean scores of each exam with standard errors in academic years of 2009 (Paper Homework) and 2010 (Online Homework) for the Mechanics of Material course.

Two independent groups of students in fall 2009 and spring 2010 of the mechanics courses were compared based on their midterm and final test scores. The two independent groups from two different academic years (2009 prepared with paper homework vs. 2010 prepared with online homework) were treated as the between-subjects effect to test the effectiveness of using an online homework system for knowledge retention. The two different test (the midterm and the final tests) scores within each group were treated as the within-subjects effect to test if there was any significant difference between the two different tests. Considering the between-subjects effect and the within subjects effect, the 2 × 2 mixed-design (split-plot) ANOVA was used to analyze the data. The ANOVA analysis shows the results from the mixed design analysis. There was a significant difference between the two groups in 2009 (previously prepared via paper homework) and 2010 (previously prepared via online homework), $F(1, 143) = 21.869$, $p < .0001$, meaning that the overall test scores in the paper homework group were significantly lower than the ones in the online homework group. The significant overall difference among the two different tests (midterm and final exams), regardless of which group the students belong to, was found, $F(1, 143) = 31.89$, $p < .0001$.

Another type of analysis used to compare the two groups was found to be consistent with the ANOVA analysis reported above. The effect size value was computed as a measure of distance between the midterm test in 2009 (paper homework) and the midterm test in 2010 (online homework), and the distance between the final test in 2009 and the final test in 2010. The visual representation of effect size values is provided in Figure 5. The midterm test showed a small effect with the effect size value of 0.263, and the final exam showed a large effect with the effect size value of 1.104. In other words, there was a distinct difference in the final exam scores between students prepared assigned paper homework and students prepared via graded online homework assignments in the previous courses.

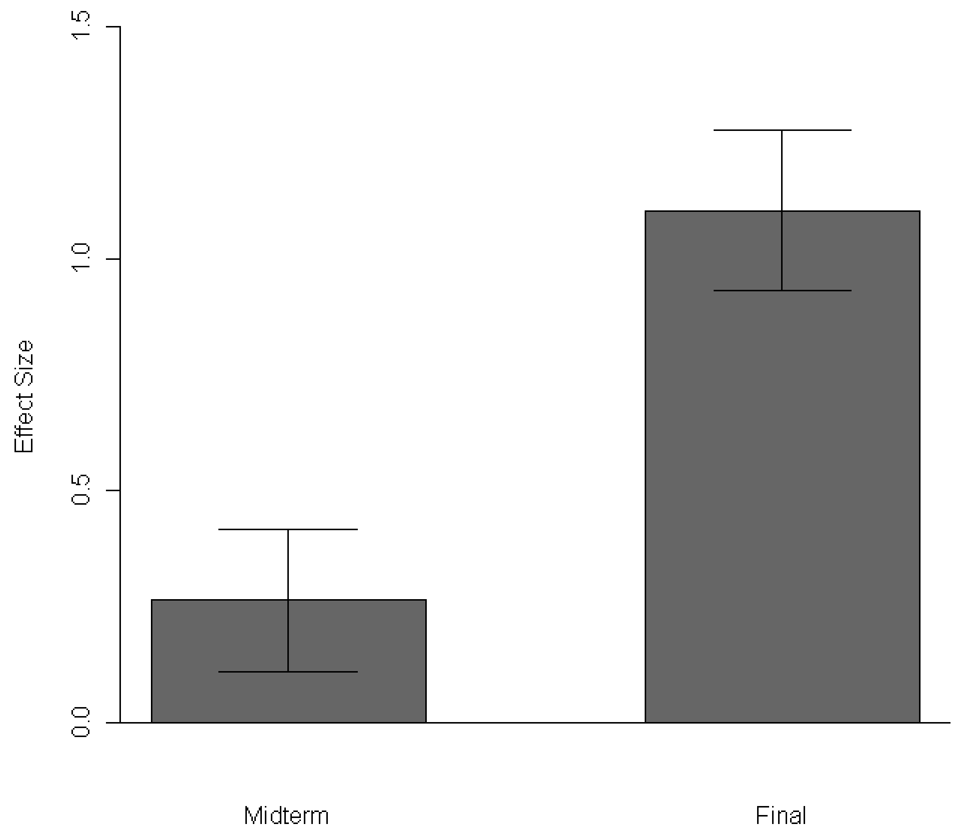

Figure 5. The values of Effect Size with standard errors for each test between Paper Homework and Online Homework for the Mechanics of Material course. The positive value of effect size indicates the improvement affected by using an online homework system. The effect size of 0 means that there is no difference between Paper Homework and Online Homework, that is, no positive effect of using the online homework system.

Concept level analysis of conceptual statics test

There was an opportunity to run another analysis, specifically on conceptual understanding in the 2009 course. This part of the analysis does not compare written to online homework assignments. Rather, its goal was to delve more deeply into student understanding of core statics concepts as defined by a nationally recognized standardized test. We now explore the item analysis in detail.

Engineering students must possess a solid understanding of basic statics concepts in order to succeed in subsequent courses for which statics is a prerequisite. Students were given a conceptual test, known as the Concept Assessment Tool for Statics (CATS), or the Statics Concept Inventory. Developed by Frontiers in Education, the CATS was designed to identify student misconceptions in statics. It contains 27 multiple-choice questions that focus on nine individual concepts (see Table 4). More than 2,500 students at more than 20 universities have taken the test. It requires students to demonstrate conceptual understanding, but few computational skills are required. The goal of the study was to examine individual item level difficulty during the pre- and post-tests, and then compare the differences using an item response model. Students were given the Concept Assessment Tool for statics test twice during the course: once at the beginning as a pre test and once at the end as a post test. Although each item was analyzed for the study, this paper reports only on the findings around the general concepts to which the individual items belong.

Table 4. The nine unique Statics concepts included in the Statics Concept Inventory.

Concept	Abbreviation	Description
1	FBD	Separating bodies and recognizing forces
2	3rd Law	Newton's third law
3	Static Eq.	Static equivalence of force and couple systems
4	Roller	Force between a roller and contacting body
5	Slot	Force between a pin and body with a slot
6	Neg. Fric.	Contacting bodies with negligible friction
7	Repres.	Representing forces with variables and vectors
8	Friction	Friction force at most equal to slipping limit
9	Equil.	Conditions of equilibrium

Pre and post test results on a nationally recognized conceptual statics test were analyzed. The pre test was administered at the beginning of the 2009 course. Thus, we can consider the pre test scores as the base scores not affected by the course instruction or homework. The mean scores (in percentages) of pre, post, and final exams were 26.61 (*SD* = 12.02), 46.3 (*SD* = 19.57), and 78.51 (*SD* = 8.32), respectively (see Table 5). There were no outliers detected in each test and the medians of each test distinctively improved from the pre through the final tests.

Table 5. Descriptive statistics of Pre and Post test scores in the Statics course in 2009.

Test	N	Mean	SD	Median	Min	Max	SE*
Pre	43	26.61	12.02	25.93	0	55.56	1.83
Post	48	46.3	19.57	48.15	14.81	96.3	2.82

***SE: Standard Errors**

When compared to the pre test stage, 93% of the items in the Statics Concept Inventory showed decreased difficulty in the post test stage—an indication that students experienced learning gains in the concepts assessed via the items by the end of the semester. Figures 6 and 7 show the concept difficulties assessed by the Rasch Model (item response model) at the pre- and post test stages. The difficulty is in standard deviation units where 0 means average difficulty and +1, for example, means a difficulty level of one standard deviation above average.

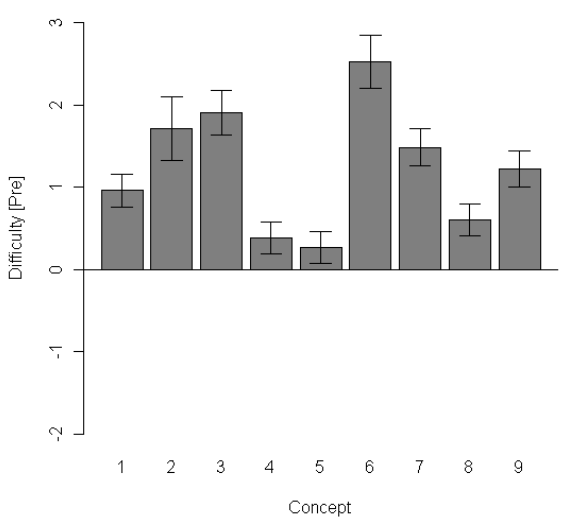

Figure 6. Concept difficulties at the pretest stage.

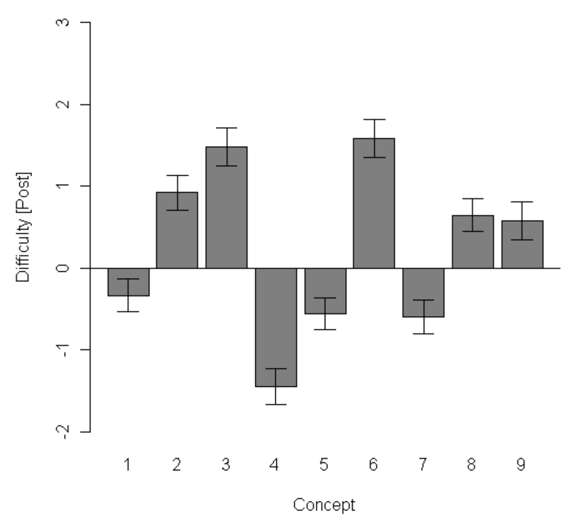

Figure 7. Concept difficulties at the post test stage.

The change of concept-level difficulty from pre to post test is presented in Table 6 and in Figure 8. Negative values indicate that the concepts became easier at the post test stage as compared to the pre test stage. All concepts, with the exception of friction, showed a reduction of difficulty by the end of the semester compared with students' understanding at the start of the semester.

Table 6. Changes in concept-level difficulties from pre to post tests in standard deviation units.

Concept	Abbreviation	Difficulty Change from Pre to Post
1	FBD	-1.30 ± 0.28
2	3rd Law	-0.79 ± 0.44
3	Static Eq.	-0.42 ± 0.36
4	Roller	-1.84 ± 0.29
5	Slot	-0.82 ± 0.27
6	Neg. Fric.	-0.95 ± 0.40
7	Repres.	-2.08 ± 0.30
8	Friction	0.04 ± 0.28
9	Equil.	-0.64 ± 0.32

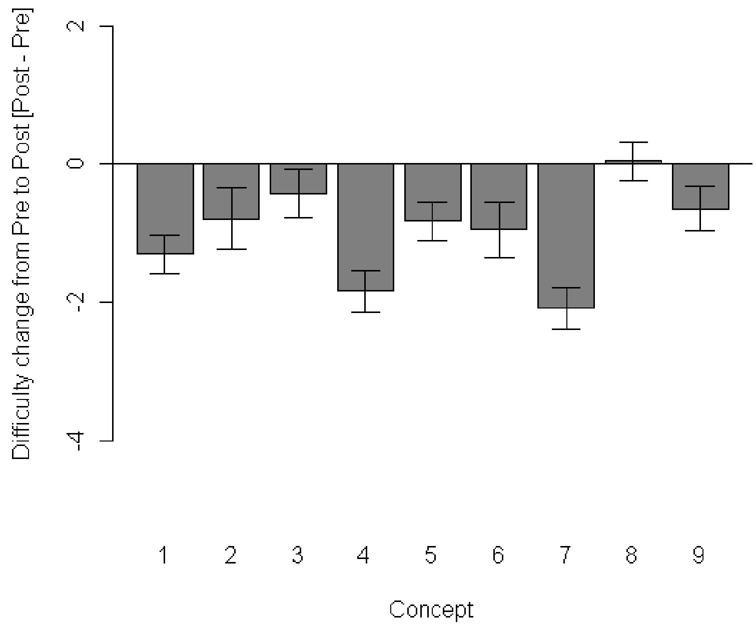

Figure 8. Change in Pre to Post tests difficulty for each concept.

From the concept analysis, students showed learning gains in eight of the nine concepts. On average, the difficulty from pre to post test decreased about one standard deviation. This also indicates a skill gain of one standard deviation on average by the end of the course.

V. Conclusion

The comparison between the students completing paper homework assignments in the statics course (in 2008) and the students using an online homework system with randomized variables and immediate feedback in the statics course (in 2009) based on the midterm and the final test scores showed the positive effect of using an online delivery system. Since the students in two different groups (statics course in 2008 paper homework vs. statics course in 2009 online homework) are all majoring in the engineering field and the SAT mean scores for the two different groups were not different, the students in the two different groups were assumed to have the same background knowledge level before the statics courses began. Under this assumption, the students' learning was considered to commence from similar starting points and the students' performances on the midterm and the final tests could be compared between the two groups. All other course elements remained the same i.e. the same number of homework problems were assigned and the time spent by the students on homework assignments were approximately equal. Furthermore, the students in both groups were instructed by the same professor and used the same lecture notes published on Blackboard™ by the instructor outside the class room. Higher mean scores observed on both midterm and final tests in 2009 using online homework than in 2008 using paper homework could be interpreted as the positive effect of using online homework systems in students' learning in the statics courses.

Students who completed paper homework assignments in their statics course in 2008 went on to take the subsequent mechanics course in 2009. They were compared against students who completed online homework assignments in their statics course in 2009 and then went on to take the subsequent mechanics course in 2010. We compared the two mechanics courses in the two academic years based on the students' performance on the final tests. We assume that students' background knowledge levels before the mechanics courses were similar. Since the previous statics courses did not cover the mechanics concepts, the students' knowledge levels between the two mechanics courses would be about the same, even though the students' previous performance on the final tests in the statics courses were different. In the previous statics courses, the group with online homework experience performed better on the final test compared to the group with paper homework. More improvement in 2010 than 2009 could be interpreted as a positive effect of using an online homework system.

In the 2009 statics course, students were given a pre test, Statics Concept Inventory, before the start of the course. The same test was administered at the end of the course. The item level analysis for the 27 individual questions in the pre and the post tests was conducted in order to investigate the item difficulty changes from the pre to the post tests. In addition, the concept level analysis for the nine different concepts in the pre and the post tests was carried out to observe the concept difficulty changes from the pre to the post tests. Both analyses showed that the questions in the post test became easier for the students, compared to the pre test except for the "friction" concept. One of the reasons why the post test became easier for the students in 2009 could be attributed to an online homework program helping the students learn and improve their performances along with other factors including the natural learning over the course. The significant correlations between the nine concepts in the post test and the final test, compared to the non-significant correlations between the pre test concepts vs. the final test were caused by the students' learning during the course. This means that after the students' learning occurred, the meaningful relationship between the Statics Concept test and the final test in the statics course could be observed.

VI. Discussion

The benefits of the online homework system are clearly identified in statistically and educationally significant improvements in student learning. Students completing the statics course after using an online homework and tutoring system outperformed those students who used paper / pencil assignments. Furthermore, these learning benefits were extended to the next course, mechanics of materials. Based on student surveys, students found the online homework system to be a useful tool for their study time. Finally, the study yielded specific pieces of information for the instructor of the course.

Based on the results of the concept level analysis from the Concepts Assessment Tool for Statics, the statics instructor received information helping to inform his future classes. In this case, the analysis flagged friction as a potential problem area. This information requires additional follow up. Some questions worth considering could be 1) should students be assigned more homework on friction items; 2) should more instruction be offered at a slower pace when friction is covered? The take away message here is that this type of educational research can be used to provide instructors with *actionable* information that can in turn be used for course improvement. We invite the engineering community to further develop and employ standardized conceptual tests as a baseline for useful comparisons in future studies.

The larger question remains, however, if these early benefits are unique to this particular school setting. We recommend that more studies of a similar nature be tested at other institutions. Nothing surpasses repeatability, especially in different course settings. Another unanswered question is while we see early evidence of learning retention, we are still interested in documenting the longer term learning gains. As the Fundamentals of Engineering (FE) exam is pivotal to the career of an engineering student, we propose revisiting the students from the 2009 statics course to review their performance on the FE.

The success of this initial program would lay a foundation for similar future programs in other core engineering courses. The use of online homework techniques could be expanded to courses such as mechanics of materials, fluid mechanics, and thermodynamics, among others, if and when publishers provide these tools. As with the objectives of this current proposal, such an expansion would lead to improved understanding of the material for advanced classes, as well as improvement on professional test scores such as the FE.

In conclusion, online homework systems provide a unique opportunity for data mining to better inform instructors on student performance. More studies of this type are encouraged. Although it is generally not possible to perform a perfectly controlled experimental study, due to ethics, educational research projects such as this one can provide actionable information to the instructor, which will ultimately benefit students.

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