AC 2011-1773: GOING ONLINE WITH STATICS

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Going Online with Statics

Abstract
Statics is a foundational course found in engineering programs across the country. Through a grant from the National Science Foundation, Carnegie Mellon University developed an online version of Statics that is freely available over the web. The materials include text material, animations, film clips, self-assessments and many other features thought to improve student understanding and motivation. The materials have been utilized in studies across the country, but always in conjunction with traditional classroom sessions. In this study, we have attempted to offer a fully-online version of the statics course. The instructor was available for one-hour per week to answer questions in a face to face meeting, but students worked through the statics topics from the online materials on their own and completed quizzes associated with each of the 18 modules available. To assess the effectiveness of this teaching method, the Statics Concept Inventory was administered to the students in the online course as well as to those in a "traditional" statics course, taught by an experienced professor both pre- and post-course. Common questions on exams were administered for students in the online and traditional courses as well as a fully common final exam. At the end of the semester, students in the online course were given an attitudinal survey regarding their feelings in taking a fully online course. Results from these assessments will be presented in this paper.

Introduction
According to Wikipedia: "Statics is the branch of mechanics concerned with the analysis of loads (force, torque/moment) on physical systems in static equilibrium, that is, in a state where the relative positions of subsystems do not vary over time, or where components and structures are at a constant velocity. When in static equilibrium, the system is either at rest, or its center of mass moves at constant velocity." (http://en.wikipedia.org/wiki/Statics, viewed January 17, 2011). Statics is one of the foundational courses taken by students in most engineering programs across the country, perhaps across the world. For this reason, teaching Statics is typically a significant service load for the department tasked with this job. At Michigan Tech, for example, Statics is taught to more than 500 students each year.

The Open Learning Initiative (OLI) was established at Carnegie Mellon University in 2002, with support from various funding sources since its inception (The William and Flora Hewlett Foundation, The Bill and Melinda Gates Foundation, The Lumina Foundation, and The Kresge Foundation). The stated goal of the OLI initiative is (http://oli.web.cmu.edu/openlearning/initiative, viewed January 17, 2011.):

> "Using intelligent tutoring systems, virtual laboratories, simulations, and frequent opportunities for assessment and feedback, the Open Learning Initiative (OLI) builds courses that are intended to enact instruction - or, more precisely, to enact the kind of dynamic, flexible, and responsive instruction that fosters learning."

The OLI suite of courses consists of many from the STEM disciplines, including Statics, Statistics, Causal and Statistical Reasoning, Biology, Biochemistry, Chemistry, and Physics. The courses are typically free or available for a modest cost and can be used to support the “anytime, anywhere” learning that is in sync with today’s generation. Most of the courses on the OLI site have received additional funding for their development. The Statics course was developed by Dr. Anna Dollar (University of Miami-Ohio) and by Dr. Paul Steif (Carnegie Mellon University) through grants from the National Science Foundation, with current grant support in the form of a CCLI Type 2 award (DUE-0918271).

The Experimental Course

Up until this time, the OLI Statics course has primarily been utilized as an enhancement to teaching in “regular” statics instruction. The OLI materials supplemented the materials presented in class. In some cases, the OLI materials have replaced required textbook materials for given courses. In this experiment, the decision was made to attempt to teach Statics using a “purely” online format; however, a few modules are not yet available through the OLI Statics course (Friction and 3-D Statics), so a hybrid method was adopted. For this study, the following format was implemented:

- Modules from OLI Statics were assigned each week of the semester. The modules include quizzes and students were required to complete the quizzes as part of their grade in the course.

- On Mondays, the Statics class would meet for an hour. Prior to class, the instructor would review quiz results from that week to determine areas of student difficulty and would specifically address those areas through examples during class time. In addition, students could ask questions regarding the material for the week during that one-hour session as needed. Most of the class time was spent discussing answers to quizzes.

- Lectures on the “missing” topics were prepared and delivered during these Monday sessions towards the end of the semester.

- Practice problems for all modules were posted on Blackboard (along with solutions) so that students could gain additional experiences in solving Statics problems.

A total of 30 students signed up for the course. Two dropped the course over the semester, leaving a total of 28 who were still enrolled at the end of the semester.

The Comparison Course

The classroom portion of this educational experiment was presented in the form of a recitation. Since Statics at MTU is a three credit course, there were three fifty minute recitations per week. Each recitation period was opened with a request for student questions. On most days there were one or two questions brought forward. Most questions relate to the homework assigned in the previous period. Following the time allotted for questions new topical material was presented using prepared slides, a tablet PC, and "Classroom Presenter" software. Prepared slides were augmented in class in real time. The unaugmented slides were made available electronically to the students prior to each week's classes. Two or three examples demonstrating the application of the topical material concluded each recitation. While the figures and problem statement associated with each example was displayed using Classroom Presenter. The detail for each solution was added in class using the tablet PC. Questions about each solution were fielded as the example was completed.

In order to reinforce/develop student understanding of the principals presented in each recitation, three to four homework problems were assigned daily. Weekly, a compilation of these assigned homework problems was collected from each student and three problems were selected by the instructor for grading. The same three problems were graded for each student. Problems for grading were chosen after homework submission. Thus, to ensure a high homework score students were required to complete all the assigned homework. In order to make the grading task more manageable, homework was only collected in the weeks when no exam was given. Each student's final grade was computed with a 9 % contribution from homework, 66 % from the midterm exams, and 25 % allotted to the final exam.

The size of the recitation section in this study was initially 88 and ended the semester with 85. The classroom atmosphere was informal with questions being welcomed at any time. Certainly with this number of students some felt reluctant to question in class. The ability to schedule appointments with the instructor along with twelve set office hours per week was made available if students required additional time or a more personal environment. Ninety minutes was allotted for the completion of each exam. These exams were composed with a sixty minute completion time in mind to remove time pressure felt by students. No more than three students remained at the end of any midterm exam.

Assessment

To assess the efficacy of the online course, three techniques were employed: 1) student gain scores on the statics concept inventory were compared between the online and recitation sections, 2) student performance on common exam items were compared across the two groups, and 3) students in the online section were given an attitudinal survey at the end of the semester to determine their feelings regarding the online course. The following sections describe the results from this analysis.

Concept Inventory Results

A total of 66 students took the Concept Inventory (CI) from the recitation course and 24 students from the online course; however, only 24 students from the recitation course took the post-CI and 14 students from the online course took the post-CI. Table 1 includes the data from the pre- and post-testing. The maximum score on the CI is 27 points).

Table 1. Results from Pre- and Post-Testing with the CI

	Online course	Recitation course	Significance of Difference between Means
Average pre-test (n)	7.92 (24)	6.41 (66)	$p<0.05$
Standard Deviation	4.66	2.52	
Average post-test (n)	12.00 (14)	11.96 (24)	N.S.
Standard Deviation	5.79	4.06	

Although there was a significant difference between the pre-test scores between the two sections, with the students in the online course outperforming the students in the recitation course, there was no significant difference at the post-test. Thus the students in the online course ended up, on average, at the same level of understanding of basic statics concepts when compared to the students in the recitation section.

Performance on Common Test Items

There were three exams offered in each course at the same time during the semester. For each of the exams, a common test item was included between the two sections. On the first test, the common question involved computing the unstretched length of a spring in a 2-D concurrent force system (Figure 1). In this question the value of the force P and spring constant k was supplied and the students were asked to calculate the unstretched length of spring AC . On the second exam, the common question involved solving for an equivalent force system for a beam subjected to various point loads (Figure 2). This question asked the students to replace the force system acting on the beam by two different equivalent systems. On the third exam, the common question involved solving for the forces acting in a member of a 2-D frame (Figure 3). In common question 3 students were given the value of P and asked to calculate all the force acting on member A-B-D. The test questions were graded by the same person (Vilmann), avoiding any bias that might occur due to differences in grading schemes.

For the first exam, due to a miscommunication between the two authors, the students in the online course had a slightly more difficult problem in that they were required to solve for the geometry of the system whereas in the recitation course, the geometry was provided for them. Further, the students in the recitation course were told that failure to include a Free Body diagram (FBD) would result in a deduction of one-third to one-fourth of the points on a problem. Students in the online course were not given this instruction.

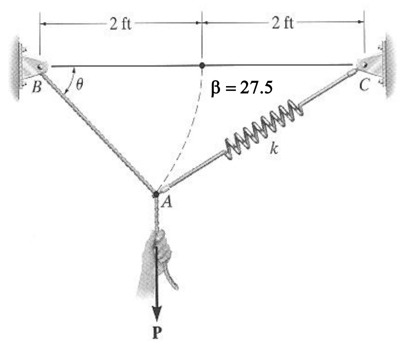

Figure 1
Figure for Common Question 1

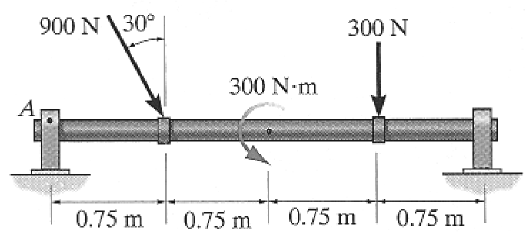

Figure 2
Figure for Common Question 2

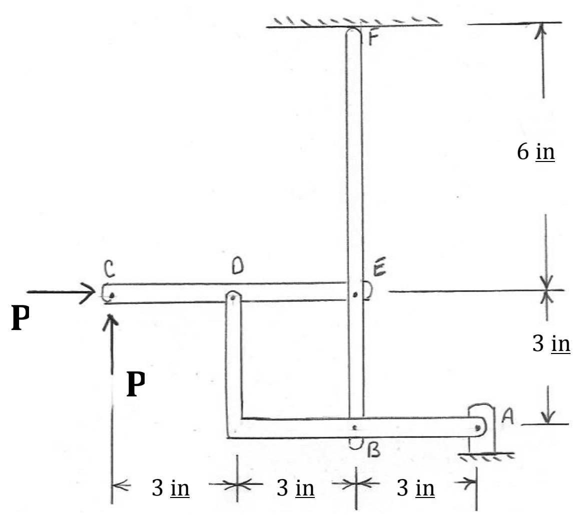

Figure 3
Figure for Common Question 3

Table 2 includes the results from the questions on the three mid-term exams. For exam #1, an "Adjusted Scores" row is included for those students in the online course who essentially worked the problem correctly but who did not include a FBD. There were 33 points possible for each problem.

Table 2. Mean Scores from Common Test Items

	Online Course	Recitation Course	Significance of Difference in Means
Test #1 (Std Deviation)	23.82 (9.63)	27.43 (8.19)	$p<0.05$
Test #1 Adjusted (Std Deviation)	24.96 (9.74)	27.43 (8.19)	N. S.
Test #2 (Std Deviation)	24.14 (8.81)	17.10 (10.06)	$p<0.001$
Test #3 (Std Deviation)	9.93 (8.33)	24.29 (8.30)	$p<0.0001$

For the first two tests, it appeared that the students in the online course performed as well as or even better than the students in the recitation course. Recall that the students in the online course solved a slightly more difficult problem, so their scores were expected to be slightly lower on this item. However, on the third test, it appeared that the students in the online course performed significantly worse. Further, for the online course, the average on the first two exams was ~75% but the average on the third exam was ~55%. Based on these results, the online course was modified for the final two weeks of the semester to include problem-solving sessions three days per week instead of just one day per week. In these extra sessions, a variety of problems were solved as a class activity each day.

The MEEM Department at Michigan Tech has a policy to utilize common final exams for core course such as Statics. For the semester when these sections were offered, the common final exam consisted of five problems. The first problem involved determination of the centroid and moment of inertia for a T-shaped cross section (Figure 4). The second problem involved determination of the forces in truss members AJ, JI, and JC (Figure 5). The third problem involved determination of the maximum mass M suspended from a pulley with no slipping of blocks on an inclined plan (friction)(Figure 6). The fourth problem involved solving for internal forces acting on member B-D-E in a 2-D frame (Figure 7) and for the final problem of the exam, students were to solve for reactions on member A-B-C-D a 3-D force system(Figure 8).

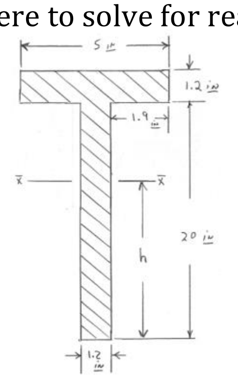

Figure 4
Final Exam Problem 1

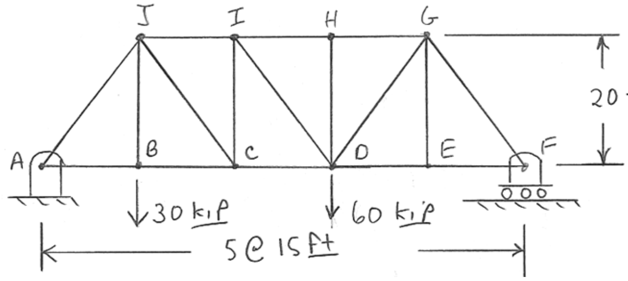

Figure 5
Final Exam Problem 2

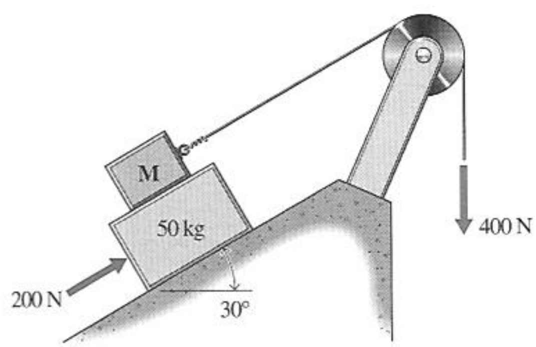

Figure 6
Final Exam Problem 3

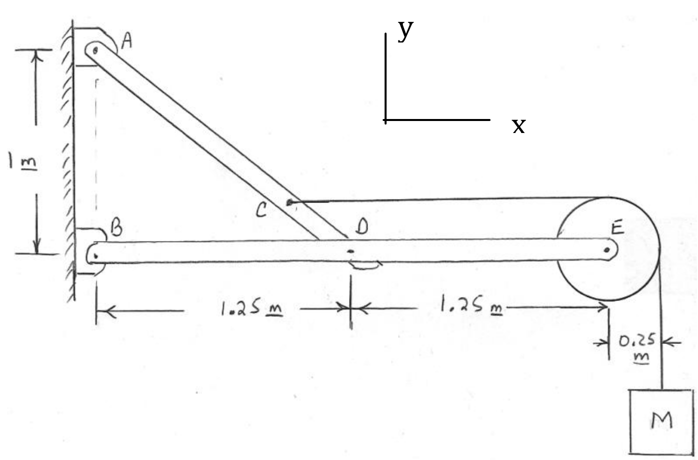

Figure 7

Final Exam Problem 4

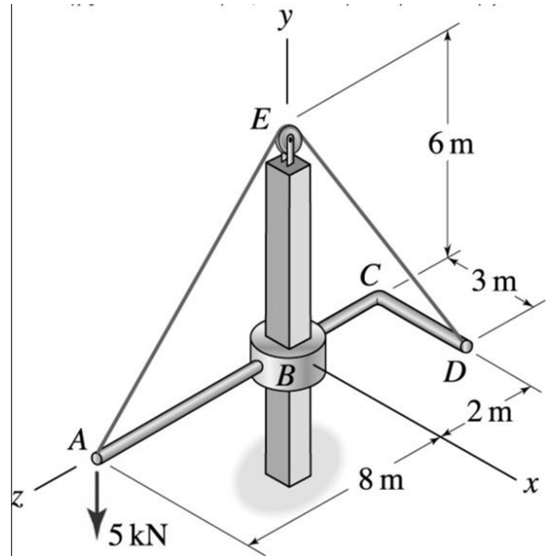

Figure 8
Final Exam Problem 5

It should be noted that for problems 3 and 5, there were no online resources available on the OLI site. Although there was a lecture given on these topics, the amount of time spent on these topics in the recitation course was one week (three class periods) or more compared to just one hour in the online course. Further, for the online course, there were four students (of 27) who appeared to have given up by the time the course was over and scored close to zero on the final exam. For the recitation course, there was one student in this category. These students were eliminated from the analysis of final exam performance. Each problem on the exam was graded by the same person to eliminate inter-rater reliability . Table 3 includes data from the final exam performance.

Table 3. Final Exam Item Analysis

	Online Course	Recitation Course	Significance of Difference in Means
Problem #1 Avg (Std Deviation)	22.96 (9.20)	20.72 (8.85)	N.S.
Problem #2 Avg (Std Deviation)	22.83 (7.49)	25.56 (6.38)	$p<0.05$
Problem #3 Avg (Std Deviation)	15.87 (6.78)	19.06 (6.36)	$p<0.025$
Problem #4 (Std Deviation)	19.65 (8.21)	23.58 (6.41)	$p<0.01$
Problem #5 (Std Deviation)	10.43 (6.23)	15.65 (7.75)	$p<0.001$

From this data, it is apparent that even though the post-test scores for the students in the two courses were equivalent, their performance on the final exam was not. In this case, the students in the online course did not perform as well as the students in the recitation course on four of the five questions of the final exam.

Results from Attitudinal Survey

An attitudinal survey was administered during the final two weeks of the semester. Of the 19 students who responded to the survey, only five indicated that they knew the course would be online when they signed up for it. This result is surprising in light of the fact that a message was embedded in the registration materials informing students that the course was going to be online. Further, the course was scheduled for only one hour per week in the scheduling materials and it seems reasonable to expect students to understand that 3-credit courses generally meet for three hours per week and to therefore investigate things further. All but three of the students said they registered for the course because it best fit their schedule.

Most of the students (12 of 19) indicated that they spent 1-3 hours per week on average on the online Statics course. This means that on average, the students in the online course likely spent far less time than the students in the recitation course (they spent 3 hours per week in lecture plus homework assignments). This result is also surprising in light of the fact that the faculty member for the course (Sorby) who has a PhD in Solid Mechanics and was not learning the material for the first time, spent more time than that going through all of the computer modules to ensure that she understood what the students were experiencing.

Students were also asked to indicate how many times through the semester that they attended the Monday sessions. Here the responses were mixed: six students said they attended once or twice, five students said they attended most of the time, and the remaining seven students said they attended always. From the instructor perspective, there appeared to be about 15 students (half of those enrolled) who attended each week.

A series of questions were asked where the responses were either 0, 1, 2, 3, or 4 and where the scale was given as:

0 Strongly Disagree
2 I don't care either way
4 Strongly Agree

Table 4 includes the results, in terms of average scores, for this portion of the survey.

Table 4. Attitudinal Survey Results

I think:	Average Response
The class sessions on Monday were an important part of my learning	1.63
The MEEM Department should continue to offer an online version of Statics	2.37
One hour per week of class meeting time was adequate	1.84
I feel prepared to complete courses for which Statics is a prerequisite (e.g., Dynamics)	1.79
I would recommend online Statics to a friend	1.63
I would sign up for another online course, if it were offered	1.53

From the results obtained through this portion of the survey, it is clear that the students didn't care for their experience with a primarily online course One surprising result is that the highest rated question was whether or not the MEEM department should continue to offer an online version of Statics. The response to this question averaged slightly above neutral; whereas, the responses for all other questions in this section of the survey averaged slightly below neutral. It appears that the students recognized the potential in offering online Statics, even if they felt that this approach wasn't for them.

In open-ended comments on the survey several students commented that they felt there was a big difference between the questions asked in the online quizzes compared to the questions asked on the test. The online quizzes tended to stress theoretical thinking; whereas, the test questions were like typical, *applied*, Statics problems. Other comments on the open-ended items focused on the lack of feedback given from the quizzes. Several students provided negative feedback regarding this aspect of the OLI materials. Students did like the interactive nature of the materials and the fact that they could work at their own pace.

One interesting phenomenon occurred about midway through the semester. Some of the students made comments in class that they concerned with the lack of opportunity to form study groups to prepare for exams. Since the class met for only one hour per week, this person felt that this schedule was not conducive to interactions among peers. She then tried, through email, to generate interest in the formation of a study group, but this was only moderately successful.

Conclusions

The results from this experiment are mixed. It appears that the OLI materials can be used to help students develop fundamental understanding of Statics concepts, as evidenced by the nearly identical outcome on the Statics CI between the two groups. However, the ability to apply this fundamental knowledge to the solution of practical problems is not as well established. In fact, the students in the online course performed as well as (or even better) on only three of six of the common exam items (recall that two of the exam items—friction and 3-D Statics—were not covered by the OLI materials, so the fact that students did not perform as well on these items is no reflection on the materials themselves). It could be that students of this level of maturity (mostly second year students) are not ready for a fully online course.

Although this experiment was not 100% successful in "proving" that online Statics is a viable option at this time, there were some valuable lessons learned. If this experiment were to be conducted again, the following modifications are suggested:

- The one-day-per-week sessions should be required for all and should include solution of real-world Statics problems as well as answering questions from the OLI materials.
- Homework should be collected and graded. Although typical Statics problems (and their solutions) were posted on Blackboard, it is not clear how many students attempted these problems on their own. Blackboard usage data suggests that students accessed them, but that does not mean that they actually solved the problems. If these problems were assigned and graded, it is likely that the students would understand more readily how to apply the fundamental concepts they were learning through the OLI materials.
- More lecture time should be devoted to the Statics concepts currently missing from OLI. One lecture on friction and one lecture on 3-D problems was simply not enough.

Another exciting potential use for the OLI materials might be to establish an inverted classroom. With an inverted classroom, routine "lecturing" takes place outside of class time and time spent with the faculty member is reserved for projects, problem-based learning, modeling and simulation, and team activities. Since it is apparent that the OLI materials do an excellent job of teaching the fundamentals, this could be done outside of class and class time could be reserved for engaging activities that expand the students' knowledge of Statics. In this way, student learning could go far beyond what is routinely taught in a "standard" Statics course and our students would be better prepared to solve the problems of the coming century.