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Blended Statics: Finding an Effective Mix of Traditional and Flipped Classrooms in an Engineering Mechanics Course

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Abstract

Flipped classrooms and active learning are becoming more common in engineering education. In an attempt to reap some benefits of the flipped format while minimizing its drawbacks, we have designed and implemented a "blended" statics course. Our blended course format includes a mix of traditional lectures and pre-recorded video lectures. In a typical week, one period is a traditional lecture, and the other period is an "activity session". Before each activity session, students watch several pre-recorded mini-lecture videos and complete online quizzes to assess their understanding of the new material. In the activity sessions, students work on hands-on experiments, computer simulations, and/or problems with support from the instructor and teaching assistant. The new aspects of this statics course are: (1) the blended format; (2) the development of novel activities for the classroom and laboratory; (3) the use of a "lightboard", in which the instructor writes on a glass board while facing the video camera, to record the mini-lecture videos; (4) the flexibility for the instructor to "flip" any desired percentage of the semester's lectures; (5) the collections of videos and activities are available for instructors across multiple campuses. Direct assessments and student surveys indicate that the blended format was generally effective. Although the direct assessment data do not show a clear advantage (or disadvantage) for the blended format relative to the traditional format, the survey data show that the students generally enjoyed the blended format, and a majority preferred the blended format over traditional format courses. In particular, students enjoyed the activity sessions and thought they were beneficial. Furthermore, the activity sessions allowed the instructor to receive valuable feedback regarding students' struggles with challenging concepts. Future iterations of the course could be adapted for larger enrollments, and could use and enhance the current collections of videos and activities.

Introduction

In a "flipped classroom" course format, students learn new material via the textbook (or video lectures) on their own outside of class, and then during the class meetings they solve problems and/or perform activities with support from the instructor and/or teaching assistants. The benefits can include increased student engagement and more attention paid to individual students' needs. Potential downsides of flipped classrooms include the difficulty some students have in learning new material on their own. Flipped classrooms have been applied successfully to statics courses [1-3]. This approach was also used in a mechanics of materials course [4] and in a machine design course [5]. Analysis of the general applicability and outcomes of flipped classrooms have been treated in [6-8]. Flipped classrooms offer the opportunity for significant amounts of active learning due to the time availability during class sessions.

Active learning has been shown to be a highly effective method of learning in a wide variety of settings, i.e., independent of the classroom size, major or any other factor [9-13]. Active learning has been heavily used in engineering because of the applicability in these areas through simple experiments (or computer simulations) that students can conduct [14-15]. The applicability of active learning in statics courses is the main concern in this paper. A variety of experimental and hands-on activities have been implemented in various statics courses [16-23]. In addition, online and computer simulations can be easily implemented in classroom settings [24-29]. Some conceptual problems have also been used to increase student motivation in statics and show them real applications of the theory [30-31]. The literature mentioned here is by no means comprehensive, but it shows some of the previous work and motivations behind these teaching methodologies.

In an effort to design a teaching technique that combines the benefits of both traditional and flipped classrooms, the blended (or partially flipped) approach has been developed and applied in various disciplines, including electrical engineering [32], and in first-year mechanics courses [33]. These novel methods combine the positive aspects of traditional and flipped classrooms with the implementation of active learning to a certain extent.

This paper describes the design and implementation of a blended-format course in statics (MEE 150) in the Department of Mechanical Engineering at the University of Maine. This course was developed as part of an effort to improve instructional efficiency and quality in common courses across multiple universities within the University of Maine System. It was intended that the blended course structure and content developed in this work be available for use by other faculty teaching statics within the System.

Course Design

Our blended course format includes a mix of traditional classroom lectures and pre-recorded video lectures. In a typical week (with two 75-minute periods per week), one period is a traditional lecture, and the other period is an "activity session". Before each activity session, students watch several pre-recorded mini-lecture videos (typically 2-8 minutes each) and then complete online quizzes to assess their understanding of the new material. In the activity sessions, students work on hands-on experiments, computer simulations, or problems with support from the instructor and teaching assistant (TA). In addition, traditional weekly homework (on paper) was assigned, and traditional exams (in the classroom) were given. The course grade weighting is shown in Table 1.

Table 1. Course Grade Weighting

Component	Weighting
Online Quizzes	5%
Homework	10%
Activity Session Assignments	15%
Exam #1	20%
Exam #2	20%
Final Exam	30%

Prior the start of the semester, more than 80 mini-lecture videos were recorded, covering every individual topic in the course. The mini-lecture videos were recorded using the "Lightboard" (Fig. 1) at the University of Maine Center for Innovation in Teaching and Learning (CITL). The instructor writes on a transparent glass board (located between the camera and the instructor) and the video images are inversed in post-processing.

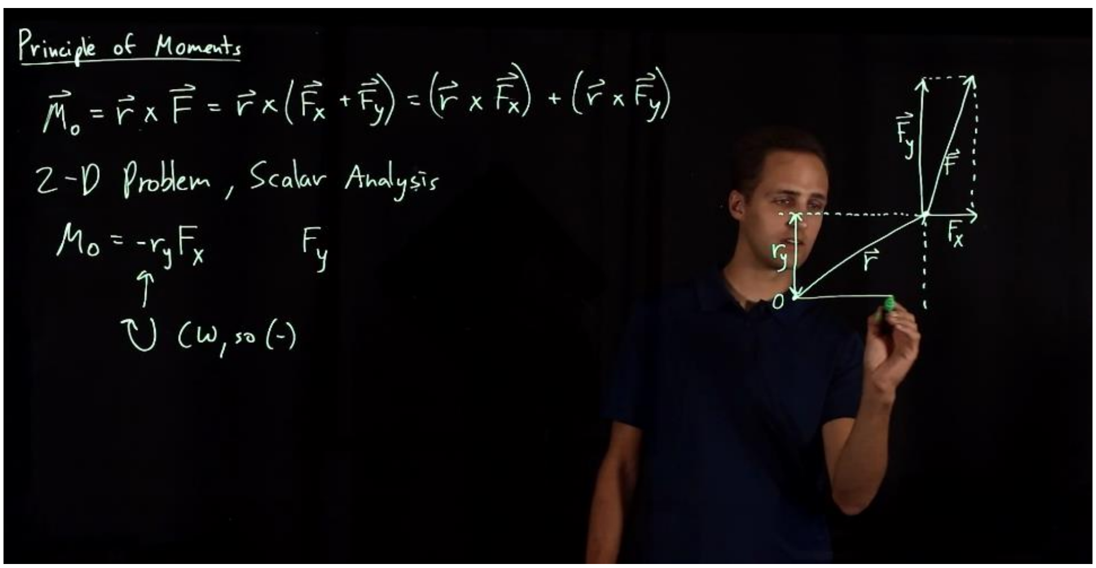

Figure 1. Screenshot of a mini-lecture video recorded using "Lightboard". The video images are inversed to make the writing readable left-to-right (this instructor is actually right-handed).

In addition, videos were recorded of the TA solving 35 different example problems (covering all the topics in the course) on a tablet at CITL. These videos captured the TA's voice and writing on the tablet. The mini-lecture videos and the "example problem" videos were posted on the course learning management system (Blackboard) website for viewing by the students.

The online quizzes were created by the instructor using the MasteringEngineering website maintained by Pearson, the publisher of the course textbook (Engineering Mechanics: Statics by R.C. Hibbeler). The primary benefit of MasteringEngineering that in each problem, the given values can be "randomized" so each student receives a different set of values. Further, students must enter the both the value and units for the answer to receive full credit.

As this was the first trial with the blended format, the percentage of flipped class periods (activity sessions) was kept below 50%. The course delivery was roughly 30% flipped and 70% traditional for this first iteration. It is important to note that our blended format gives flexibility for the instructor to "flip" any desired percentage of the semester's lectures.

Activity Sessions

For the activity sessions, students came to the classroom, laboratory or conference room, and worked on problems (chosen to be slightly more challenging than what they usually see in class), experiments and/or computer simulations/analysis. During the activity sessions, the instructor and the TA walked around the room/lab answering any questions from individual students or groups. Students were encouraged to work collaboratively in groups of two, three, or four (depending on the activity), but each student completed their own activity session assignment (which was typically due the following class period). In some cases, students were able to complete the assignments during the class period; in other cases, students finished their assignments outside of class. A description of each activity session is as follows:

Activity #1 (in classroom, Week 2): Force vectors – This activity consisted of two three-dimensional problems involving force vectors (finding the resultant of two forces, finding the force magnitude, and finding the force components parallel and perpendicular to a pole).

Activity #2 (in lab, Week 3): Particle Equilibrium Experiment – Students performed an experiment involving two-dimensional equilibrium of a mass, which was supported by two springs attached to lab stands (Fig. 2). The attachment point for scale #2 (y_3) was varied while the attachment point of scale #1 was fixed (y_1). For each geometry tested, the students recorded the resulting spring forces and vertical location of the mass (y_2). They plotted their data (spring forces as a function of y_3) using Excel, and then compared their experimental results to their theoretical calculations. Finally, they attempted to explain any differences between experiment and theory. A full description of the activity is provided in Appendix A.

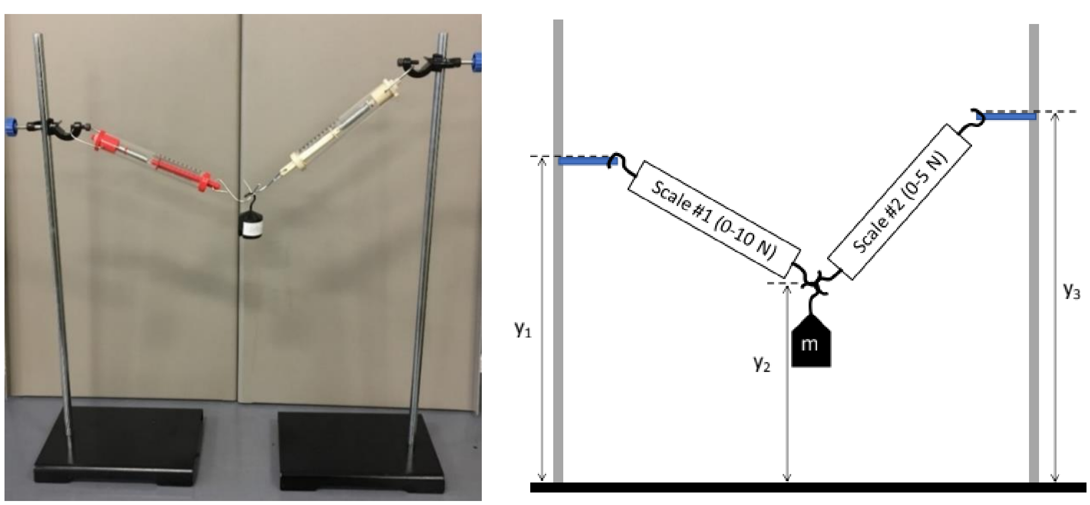

Figure 2. Activity #2, Particle equilibrium (a) experimental setup and (b) schematic.

Activity #3 (in classroom, Week 5): Moments – Student completed four problems designed to reinforce the concept of a moment caused by a force, as well as moment magnitude and direction, in both two and three dimensions.

Activity #4 (in conference room, Week 7): Rigid Body Equilibrium Analysis– Students performed a theoretical equilibrium analysis of a horizontal bar that supports a mass, and is supported by a pin and a cable. The problem was supplemented with an online simulation [34]. A full description of the activity is provided in Appendix B.

Activity #5 (in lab, Week 8): Rigid Body Equilibrium Experiment – As a follow-up to Activity 4, students performed an experiment involving a horizontal bar supported by a pin and a spring scale (Fig. 3). Students conducted tests using different attachment points on the bar, and then compared their experimental results with their theoretical calculations. In addition, students completed a conceptual problem involving an overhang supported by a rod. A full description of this activity is provided in Appendix C.

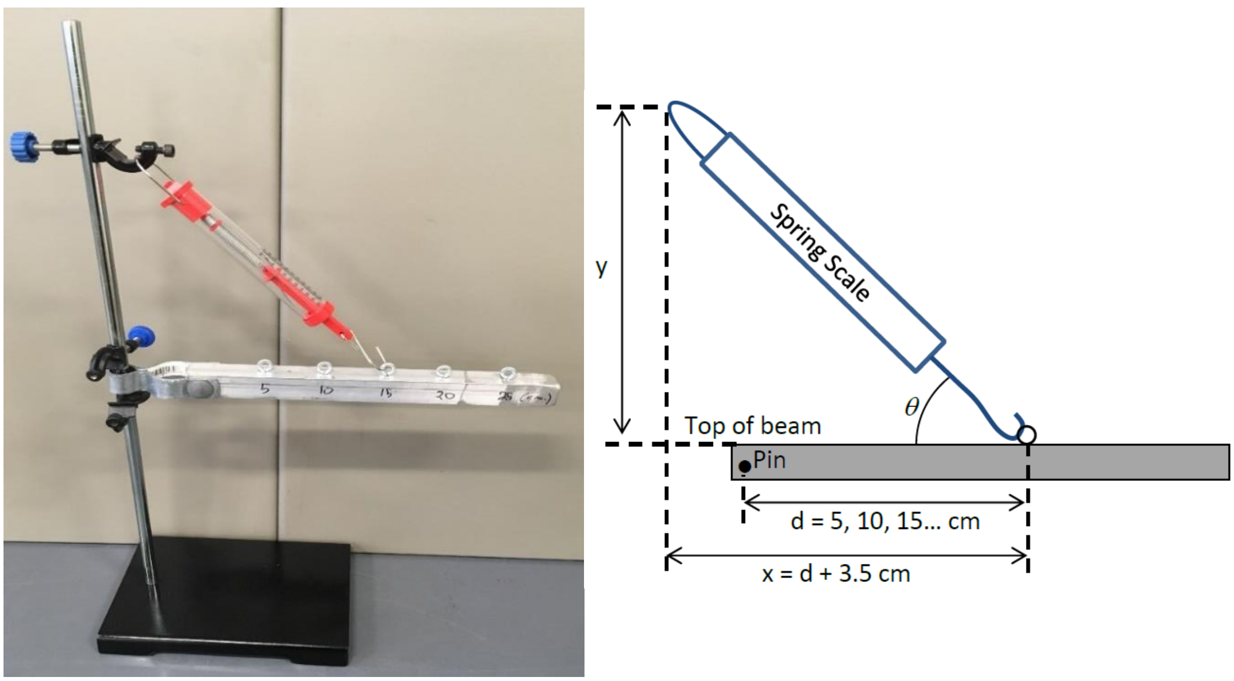

Figure 3. Activity #5, rigid body equilibrium (a) experimental setup and (b) schematic

Activity #6 (in lab, Week 10): Structural Analysis of a Truss – Students performed measurements on a truss constructed with PASCO educational equipment (Fig. 4). The forces in five members, and one support reaction, were determined experimentally for two loading cases. Students also calculated the forces using theory (either method of joints or method of sections). Full details are given in Appendix D. The students were encouraged to solve the equilibrium equations symbolically, and then substitute given values, rather than solving the equilibrium equations for each case separately. Excel was recommended for this problem, but some students chose to use MATLAB.

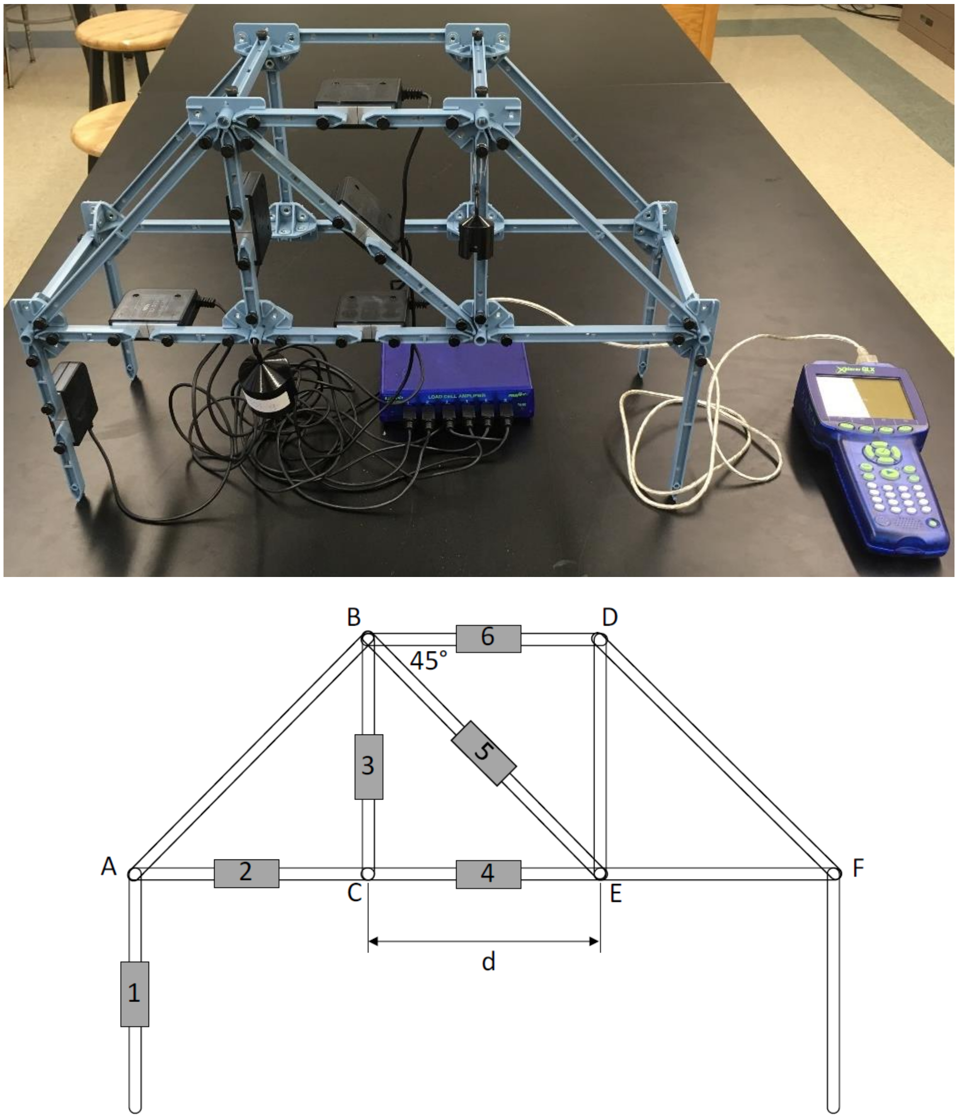

Figure 4. Activity #6, truss analysis (a) experimental setup; (b) schematic showing the six load cells.

Activity #7 (in classroom, Week 14): Centroids and moments of inertia – Students completed three problems involving the determination of centroids of areas and area moments of inertia.

Results and Discussion

The students completed mid-semester and end-of-semester customized surveys. Table 2 shows the quantitative results of the course rating questions, and Tables 3 and 4 show a representative sample of the student responses to open-ended questions on the end-of-semester survey.

Table 2: End-of-semester survey question results for blended format

	Lecture Sessions	Average (5 = Strongly Agree; 1 = Strongly Disagree)
1.	The in-class lectures were clear and easy to follow	4.79
2.	The in-class lectures were beneficial and worth attending	4.84
	Videos	
3.	The video lectures were clear and easy to follow	3.21
4.	The video lectures were beneficial and worth watching	3.42
5.	The example problem videos were clear and easy to follow	3.16
6.	The example problem videos were beneficial and worth watching	3.05
	Online Quizzes	
7.	The online quizzes were beneficial to my learning	3.37
	Activity Sessions	
8.	I received helpful feedback and assistance during the activity sessions	4.58
9.	The activity sessions increased my understanding of the course material	4.58
10.	The activity sessions increased my range of skills	4.32
11.	I enjoyed the activity sessions in the lab (performing experiments)	4.11
12.	I enjoyed the activity sessions in the classroom (solving regular problems)	4.32
13.	I enjoyed the activity session in the conference room (computer simulation and problems)	3.89

Table 3. Student responses to "Please identify aspects of the course which were of most value to you."

"The activity sessions that we had approximately once a week were very helpful in understanding the material."
"The in class activity sessions were helpful to ask questions and I learned a lot from your lectures since you go through the material at a slower pace and make sure you explain everything thoroughly"
"I enjoyed the activity sessions as well as the non–traditional style lectures/online videos and quizzes."
"I liked all of the topics that were talked in class. They were very helpful and fun to learn. The professor was great and I loved his teaching style."

Table 4. Student responses to "If given the opportunity, would you take another "blended" format course (like this one) or do you prefer the traditional lecture format course? Please explain."

"Yes"
"I would take another blended course because it helped me learn how to use statics in the real world."
"I would! Works very well"
"This course was great, but it does not need the online quizzes. They are a waste of money, and offer no feedback. Paper would be much more effective."
"I would take another "blended" format course, as long as there is minimal graded assignments outside of class on material that you have on covered by yourself and not yet in class. I do not think I would enjoy a fully "blended" class where I only learned at home from videos."
"This one was good. The videos by the TA were hard to understand. He talked too fast and the marker he used was too large. The videos looked like scribbles."
"Lecture format. [Blended format] wastes time going over things that should be taught in class, and online format is not user friendly."
"I have learned that blended is the best option. It gives a chance for personal thinking and teaching as well and teacher reinforcement."
"Blended makes the course more in depth and easier to understand. It also makes the course more interesting and less "dry" than traditional lecture format can be."

The blended-format course surveys show that, in general, the students liked the blended format, and that a strong majority preferred the blended format over traditional format courses. The students generally enjoyed the activity sessions and thought they were beneficial. The instructor noticed that students showed motivation and engagement (with peers, the instructor and the teaching assistant) during these sessions. Further, the instructor and teaching assistant enjoyed teaching the blended format, and were able to get better feedback from the students (e.g., concepts with which they were struggling) due to the interactions during the activity sessions. It should also be noted that in the current blended format, students gain experience in teamwork, hands-on laboratory work, comparison of experimental data to theory, and practice with software (Excel and/or MATLAB); these skills are not typically practiced in a traditional statics course.

The survey data show some negative student feedback on the video lectures, example problem videos and online quizzes. In particular, students complained that the example problem solution videos were difficult to follow due to the fast pace and the handwriting done with the tablet pen. Quantitative data on students' viewing of the videos (e.g., number of students viewing the videos, and time spent viewing) was not retained from this offering of blended statics. For the online quizzes, the primary complaint at mid-semester was the lack of "partial credit" (an answer is either right or wrong). To compensate, at mid-semester we increased the number of attempts allowed (per question) from two to five, and decreased the penalty for each incorrect answer from 10% to 5%. Complete results of the surveys are shown in Appendix E.

Table 5 provides a side-by-side comparison of the traditional and blended versions of the statics course with regard to standard course evaluation questions that are relevant to course format. Both courses were taught by the same instructor; the traditional format had enrollments of 56 and 50 (in Spring 2018 and 2019, respectively) and the blended format had an enrollment of 21. Any effects of class size are difficult to determine, because the two traditional sections had similar enrollment. To date we have not had the opportunity to teach a traditional course with a small enrollment, or a blended course with large enrollment. Table 5 shows that the blended format scored slightly higher than the traditional format with respect to "Were class meetings profitable and worth attending?", but slightly lower on the questions "How orderly and logical were the instructor's presentations of the material?" and "Did you develop significant skill in the field as a result of taking this course?" These data do not show a clear advantage for one format over the other.

Table 5: Selected questions from standard course evaluations for comparison of the traditional and blended formats.

Question	Traditional Format Sp. 2018	Traditional Format Sp. 2019	Blended Format Fall 2018
How orderly and logical were the instructor's presentations of the material? (5-Very Much; 1-Not at All)	4.83	4.91	4.64
Were class meetings profitable and worth attending? (5-Always; 1-Not usually)	4.71	4.83	4.91
Did you develop significant skill in the field as a result of taking this course? (5-Very Much; 1-Very Little)	4.45	4.45	4.27
What is your overall rating of this course? (5-Excellent; 1-Poor)	4.50	4.66	4.64

For a direct comparison of student outcomes, the same comprehensive final exam was given each semester; the average scores (neglecting any scores of "zero" for students who did not take the final exam) were 83.2% and 89.8% (Spring 2018 and 2019, respectively) for the traditional format, and 89.5% for the blended format. The average scores on each final exam problem for each course are shown in Appendix F. These data do not indicate a clear advantage for one format over the other with regard to either overall performance or comprehension of individual topics.

It should be noted that the student populations in each class were not necessarily similar. Importantly, the Fall 2018 (blended) and Spring 2019 (traditional) sections reached capacity very early in the registration period (typically corresponding to a population of higher-achieving students). In contrast, the Spring 2018 (traditional) section never reached capacity, and therefore a considerable number of students in this section registered very late. The likely resulting differences in student populations could explain some of the differences in final exam scores.

Table 6 shows the number of students, and percentage of each class, receiving each possible grade for the course. These data indicate that the two traditional format classes had significantly different student populations, likely for reasons mentioned above. With regard to DFW grades, the blended course had no D or F grades, and only one student withdrew, yielding a DFW rate of 4.8%. However, the Spring 2019 traditional course also had a very low DFW rate of 4.0% (one D, one F, and no withdrawals). The DFW data do not indicate a clear advantage (in terms of student success) for one format over the other. However, the blended format had a higher percentage of students receiving a grade of A or A- (57%) than both traditional format courses (36% and 48%), potentially indicating an advantage for the blended format with regard to the fraction of students excelling in the course.

Table 6: Number and percentage of students earning each possible grade in each course.

Course Grade	Traditional Format Spring 2018 (56 students)	Traditional Format Spring 2019 (50 students)	Blended Format Fall 2018 (21 students)
A or A-	20 (36%)	24 (48%)	12 (57%)
B+, B, or B-	19 (34%)	12 (24%)	4 (19%)
C+, C, or C-	10 (18%)	12 (24%)	4 (19%)
D-, D, or D+	2 (3.6%)	1 (2.0%)	0
F	4 (7.1%)	1 (2.0%)	0
W (Withdrew)	1 (1.8%)	0	1 (4.8%)
Total DFW	7 (12.5%)	2 (4.0%)	1 (4.8%)

The blended course could be further improved (e.g., with respect to videos and quizzes) based on the experience of this first trial. As described earlier, quantitative data on students' viewing of the videos was not retained from this offering, but such data would be collected in a future offering of the blended course. Perhaps the largest challenge in offering this blended version of statics is the enrollment. At the University of Maine, multiple sections of statics are offered each semester, and each section typically has 30-60 students. The enrollment for this first offering of the blended format was initially limited to 20 students (21 actually enrolled), and it worked quite well. The existing course structure could easily accommodate up to 24 students. This limit is determined primarily by the laboratory experiments; we can currently accommodate six groups (with four students each) working simultaneously. Going beyond 24 students may require meeting for the experiments outside of normal class time, or scheduling multiple "lab sections". For the activity sessions in the classroom, higher enrollments should not pose a problem, as undergraduate assistants could be employed to supplement the instructor and TA.

Conclusion

In this work, we have described the design, implementation, and assessment of a statics course at the University of Maine with the following new aspects: (1) the blended format; (2) the development of novel activities for the classroom and laboratory; (3) the use of a "lightboard", in which the instructor writes on a glass board while facing the video camera, to record the mini-lecture videos; (4) the flexibility for the instructor to "flip" any desired percentage of the semester's lectures; (5) the collections of videos and activities are available for instructors across multiple campuses.

The student surveys and direct assessment data indicate that the blended format was generally effective. Although direct assessment data do not show a clear advantage (or disadvantage) for blended format relative to traditional format, the survey data show that the students generally enjoyed the blended format, and a majority preferred the blended format over traditional format courses. In particular, students enjoyed the activity sessions and found them beneficial. Additional educational benefits of the current blended format include teamwork, hands-on experience in the laboratory, comparison of experimental data to theory, and practice with Excel/MATLAB; these skills are not typically practiced in a traditional statics course. Some aspects could be modified in future iterations of the course. For example, the course could be adapted for a larger enrollment, and some videos could be improved. Finally, the blended course structure developed in this work, as well as the collections of videos and activities, can be used as desired by other faculty teaching statics within the University of Maine System.

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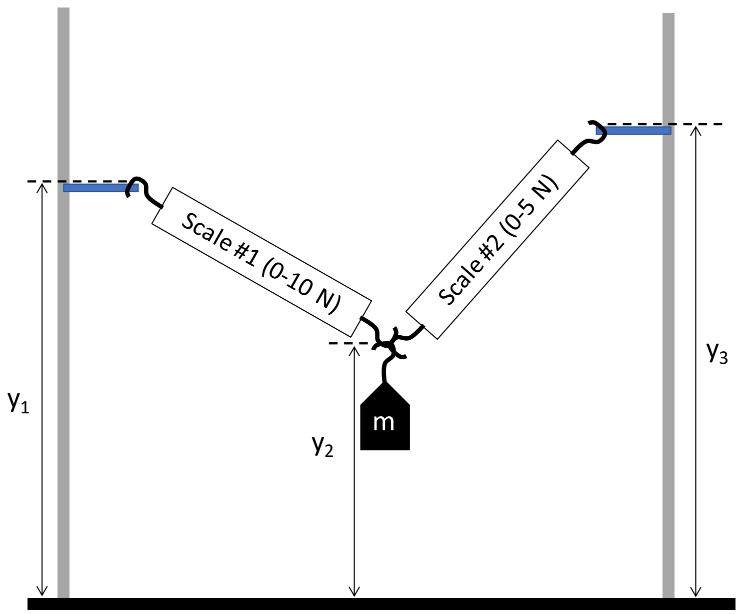
Appendix A

Activity Session #2: Particle Equilibrium Experiment

Break up into groups of 3 or 4 students and share your names & email addresses.



Fixed Variables:

- m = 500 g
- y_1 = 40 cm

Tasks:

1) Tests at least 8 different values of y_3 over as wide a range as possible. Generate a plot of the two spring forces, F_1 and F_2, as functions of y_3. Add an appropriate trendline for each data set on the plot.
2) Using your plot, estimate the y_3 such that the forces in the two springs are equal. We will call this the "optimal" value of y_3.
3) Perform a test at the "optimal" y_3. Record F_1, F_2, y_2, and the total length of each spring scale (distance from hook to hook, i.e., the hypotenuse). Clearly record all of these in your Excel sheet.
4) Make sure all group members have a copy of all the data recorded above (by hand and/or emailing Excel sheet).
5) Using the dimensions recorded in the last test, calculate the theoretical values of F_1 and F_2 for equilibrium (by hand on paper). Show all your work and put boxes around answers, just as in a regular Statics problem.
6) Compare the theoretical values of F_1 and F_2 to the experimental values, and explain any potential sources of error.

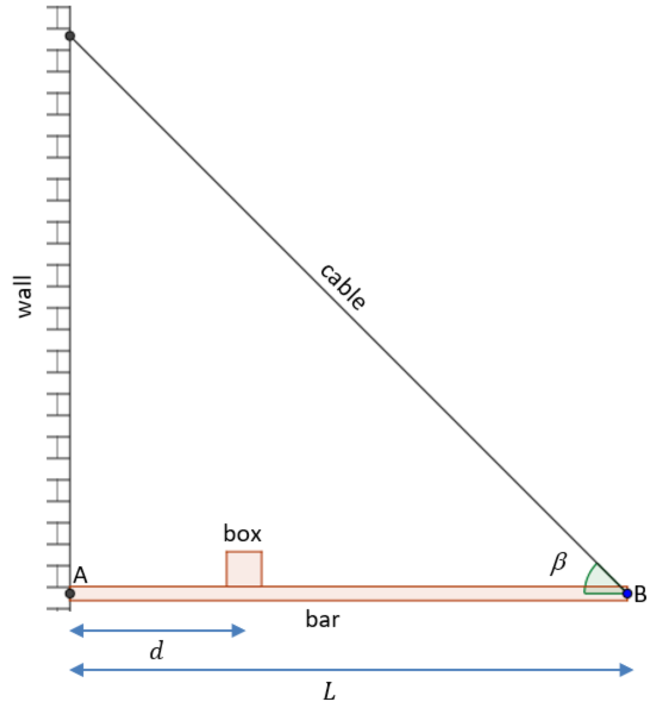
You will submit:

1) Part A (Group assignment): A printed Excel sheet for the group (Tasks 1-3 above).
2) Part B (Individual assignment): Tasks 5-6 above, by hand on paper.

Appendix B

Activity Session #4: Rigid Body Equilibrium Analysis

We will be analyzing the system shown below (from http://ophysics.com/r6.html). Assume that the bar is connected to the wall by a pin support at A.



Perform the following (staple solutions/printouts to this Cover Sheet):

1. Draw a FBD for the bar.

2. Determine three equations of equilibrium for the bar. Let T be the tension in the cable.

3. Determine the formula for the cable tension (T) as a function of the following variables:
   Mass of bar (m_{bar})
   Mass of box (m_{box})
   Length of bar (L)
   Position of box (d)
   Angle of cable (β)

4. For a 40-kg bar with a length of 8 m, a 30-kg box and a cable angle of 45°:
   a. Using Excel, plot T as a function of d for $1\ m \leq d \leq 7\ m$ (check that your values match the website).
   b. If the cable can only support a tensile force of 500 N before failing, over what range of locations (d) can the box be safely placed?
   c. For the critical case of a 500 N tensile force in the cable, determine the reactions at the pin support A.

5. For a 40-kg bar with a length of 8 m, a 30-kg box and a box location of 3 m:
   a. Using Excel, plot T as a function of β for $10° \leq \beta \leq 80°$ (check that your values match the website where possible).

6. For a 40-kg bar, a 30-kg box, a box location of 3 m, and a cable angle of 45°:
   a. Using Excel, plot T as a function of L for $4\ m \leq L \leq 20\ m$ (check that your values match the website where possible).

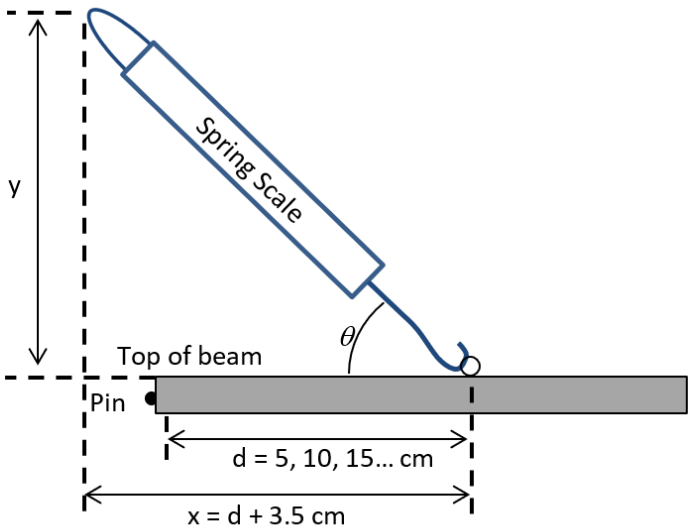
7. For a given box mass and bar mass, if we want to minimize the tension in the cable:
   a. Should we increase or decrease the bar length? (explain why, from a physical standpoint)
   b. Should we increase or decrease the box position (d)? (explain why, from a physical standpoint)
   c. Should we increase or decrease the cable angle? (explain why, from a physical standpoint)

Appendix C

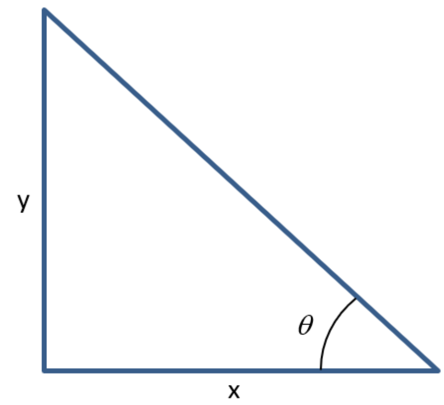
Activity Session #5: Rigid Body Equilibrium Experiment

Part (A)

In today's lab, you will test the following system:



Triangle to calculate θ:



1. Perform a test with each spring at each of the five beam locations (see table below), where possible (some of these test conditions may not be possible).
   a. After connecting the spring hook to the appropriate "eyebolt" on the beam, you must adjust the top clamp until the beam is horizontal.
   b. Record the spring force (be careful with the increments; they are different on the two scales).
   c. Measure the vertical distance "y" from the top of the beam to the top of the spring scale loop.
2. Draw a free body diagram for the beam. The beam's mass is 0.54 kg and length is 29 cm.
3. Determine the equations of equilibrium for the beam.
4. Calculate the theoretical force for each test condition (Excel is recommended).
5. Calculate the % error between the theoretical and measured force for each test condition (in Excel).
6. Describe any potential sources of error (can type this into Excel spreadsheet, or handwrite).
7. Create a plot of the Measured Force and Theoretical Force as a function of beam location (d). Make sure to include axes titles and a legend.
8. Print out your entire Excel file (including all data and the plot). Make sure the plot is not split over two pages.

Spring	Beam location, d (cm)	x (cm)	y (cm)	Measured Force (N)
0-10 N	5			
	10			
	15			
	20			
	25			
0-20 N	5			
	10			
	15			
	20			
	25			

Part (B)

"Conceptual Problem" C5-1 (*Engineering Mechanics: Statics, 14th Edition, R.C. Hibbeler, Pearson, 2016*):

The tie rod is used to support this overhang at the entrance of a building. If it is pin connected to the building wall at A and to the center of the overhang B, determine if the force in the rod will increase, decrease, or remain the same if:

(a) the support at A is moved to a lower position D
(b) the support at B is moved to the outer position C

Assume that the rod length is adjustable, so that the overhang remains horizontal!
Explain your answer with an equilibrium analysis, using assumed dimensions and loads.

Source: R.C. Hibbeler, Engineering Mechanics Statics, 14th edition

Part (C)
To summarize your findings from Parts (A) and (B): Explain how you can minimize the tension in the rod/cable (as shown in figure above) by varying the locations of the attachments to the wall and to the overhang/beam (i.e., can you choose two attachment points that are even better than the points shown on the diagram above?). In your answer, you should briefly explain why each attachment location has a particular effect on the rod/cable tension. You can assume that the attachment locations can be varied independently (unlike the experiment!).

Appendix D

Activity Session #6: Structural Analysis of a Truss

In today's lab, you will test the following truss:

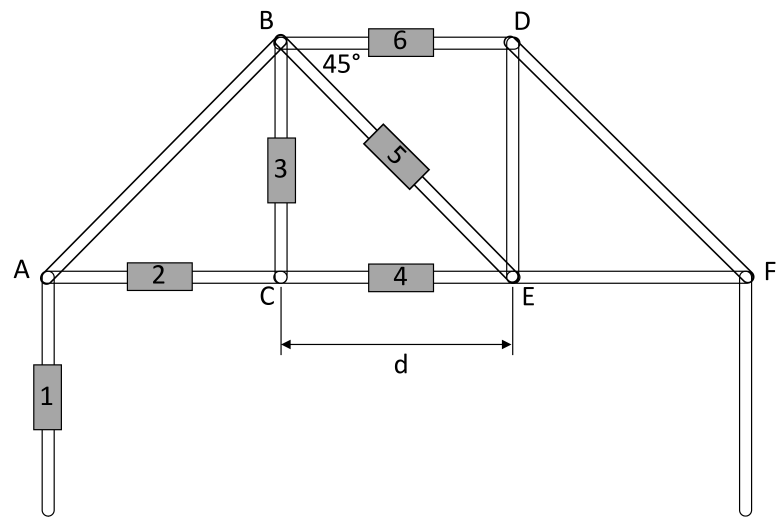


Figure 1. Truss showing the six load cells.

We are interested in the vertical reaction at support "A" and the forces in members AC, BC, CE, BE, and BD. You can assume A is a pin support and F is a roller support.

1. GROUP TASK: Measure these six forces (A_y, F_{AC}, F_{BC}, F_{CE}, F_{BE}, F_{BD}) using the load cells for the configurations (a) and (b) as shown below. Immediately before adding the masses, you should press the "TARE" button on the amplifier box (to "zero" the readings). Record your data in the table below.

   (a) Apply a mass of m_1 = 1 kg at C (hang from hole), and m_2 = 500 g at D (hang from paperclip)
   (b) Remove m_1 (i.e., m_1 = 0), but leave m_2 = 500 g at D.

   Note: the PASCO units report negative values for tension, and positive for compression.

Force	Load Cell #	Force (N) in Configuration (a)	Force (N) in Configuration (b)
A_y	1		
F_{AC}	2		
F_{BC}	3		
F_{CE}	4		
F_{BE}	5		
F_{BD}	6		

2. INDIVIDUAL TASK: Determine equations for each of the six forces force as a function of m_1 and m_2 (so that you can later plug in any values for m_1 and m_2). You can use either the methods of joints, method of sections, or a combination thereof.

3. GROUP TASK: Download the Excel template “Activity #6_template.xlsx” from Blackboard, and complete it. (Can be done individually if you like).

4. INDIVIDUAL TASK: Describe and discuss any discrepancies between your experimental and theoretical forces, and describe any potential sources of error. If one configuration results in larger % errors than the other, discuss/explain why.

Each student must submit their “individual task” work and a copy of the completed Excel spreadsheet. Staple this handout as a cover sheet to the front of your submission.

Appendix E

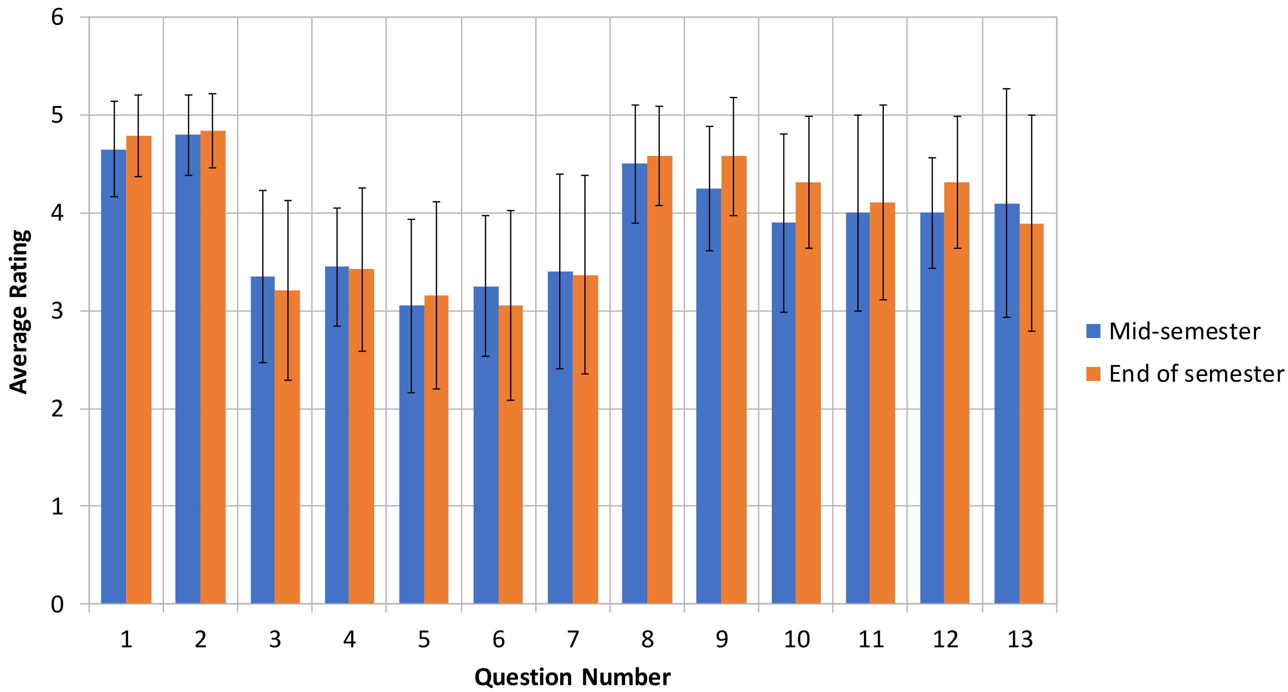


Figure E1. Quantitative survey question results (5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; 1 = strongly disagree;). The error bars represent the standard deviations.

Table E1. Quantitative questions on mid-semester and end-of-semester surveys

	Lecture Sessions
1.	The in-class lectures were clear and easy to follow
2.	The in-class lectures were beneficial and worth attending
	Videos
3.	The video lectures were clear and easy to follow
4.	The video lectures were beneficial and worth watching
5.	The example problem videos were clear and easy to follow
6.	The example problem videos were beneficial and worth watching
	Online Quizzes
7.	The online quizzes were beneficial to my learning
	Activity Sessions
8.	I received helpful feedback and assistance during the activity sessions
9.	The activity sessions increased my understanding of the course material
10.	The activity sessions increased my range of skills
11.	I enjoyed the activity sessions in the lab (performing experiments)
12.	I enjoyed the activity sessions in the classroom (solving regular problems)
13.	I enjoyed the activity session in the conference room (computer simulation and problems)

Appendix F

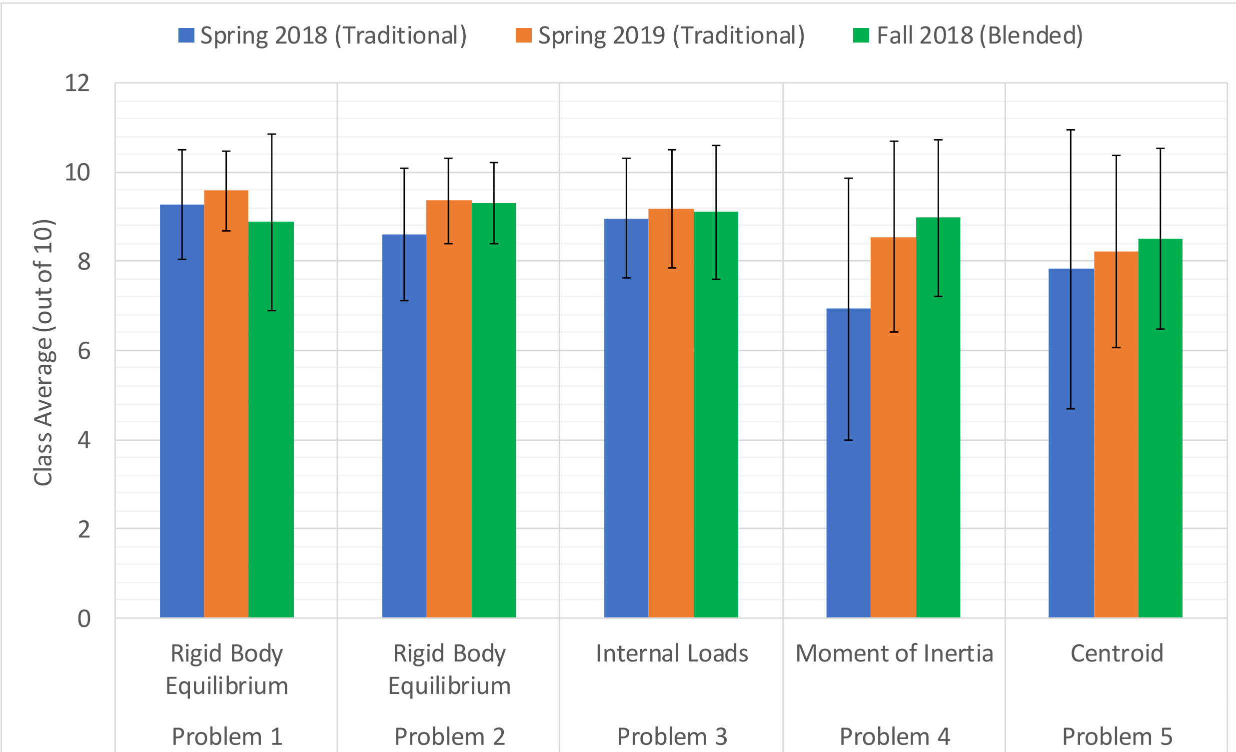


Figure F1. Comparison of average scores on each final exam problem for the traditional and blended format courses. The error bars represent the standard deviations.