Demonstrations for Class Time for Flipped Statics

Anna K. T. Howard
Teaching Associate Professor, North Carolina State University

Abstract

Flipping the classroom increases student engagement and student success. Removing most of the lecture from class can also provide the time for demonstrations and experiments enabling different kinds of learning. But faculty are very used to lecturing. Removing the lecture can lead to big questions of "What do I do with that class time?" This paper discusses several different demonstrations that were incorporated into Statics at North Carolina State University (NCSU). In prior work, faculty at Clemson University partnered with Pasco Engineering products to develop a Force Distribution System demonstration of a ball on a track with force measurements captured from each of the simple support locations.[1,2] This semester's classes included the Force Distribution System demonstration and nine other demos designed to enhance student understanding of specific concepts while taking up no more than 10 minutes of class time.

Keywords

Statics, flipped classroom, demonstrations

Section 1: Introduction

Flipped or inverted classrooms are becoming more common across the country.[3] Western Michigan, the University of Puerto Rico, the University of Wisconsin, and others have all tried a flipped Statics at least once.[4,5,6]

The pilot versions of MAE 206 Engineering Statics as a flipped class at NCSU occurred in 2010 and 2011. This first implementation of a flipped class for Statics involved no lecture at all. Students were instructed to watch a video-taped lecture from a prior class before coming. During class, students worked a few example problems and then began the homework which they turned in individually at a later time. Initial results showed more people finishing the class with passing grades and higher evaluations. The flipped class includes many aspects to engage the students.[7]

As the flipped class evolved, small bits of lecture crept back into the class. Short introductions of the material now precede students' working in groups to solve problems. Though each class varies, the teams in class are working together around 80% percent of the time.

The challenge with flipping a class was originally how to replace the lecture adequately. As technology has improved and YouTube has become ubiquitous, that question has been answered.[8,9,10] Just as not all classroom experiences are equally good, not all video presentations are equally good, but the ability to deliver content to students outside of class time is no longer contested.[11,12,13]

The new challenge with flipping a class is using the time with the students to best advantage. Initially at NCSU all the student time was spent in groups working book-type problems. Teams are still used, groups of three students selected by the instructor and rotated three times each semester.[14] Adjustments to the student activities have also been made in later semesters, allowing more class time to be directed at specific learning objectives.

But just as listening to a lecture can be done outside of class time, working book problems can also be done outside of class. This project was undertaken to discover whether simple demonstrations could be added in place of a calculation or two to aid students in understanding the learning objectives involved.

Section 2: Literature Review for Demonstrations in Statics

Hands-on Statics experiments have typically been conducted only in lab settings. Lucke and Killen describe eight hands-on models for students to work with.[15] These models do not scale up well to very large classrooms. Dong also describes hands-on activities in Statics, but decreases the class size to 32 students per section.[16] (The three sections described here averaged 108 students.)

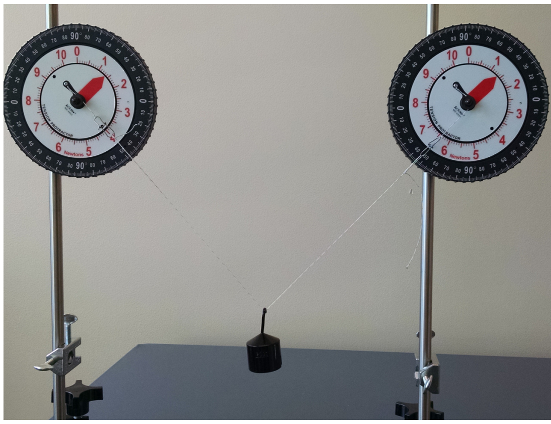
Dollar and Steif emphasize the sense of touch and the perception of motion in the activities they propose.[17] To the extent that the demonstration of motion and deformation can be performed with items that the students have already, this is doable in large classes, but purchasing even small demonstrations for the more than 125 teams involved in this project was not feasible.

Other authors and textbook manufacturers have made up for the lack of hands-on experience with virtual demonstrations.[18-21] The advantage of these is that each student can complete the demo repeatedly with no additional cost. The clear disadvantage is the lack of physical items which can be seen and touched.

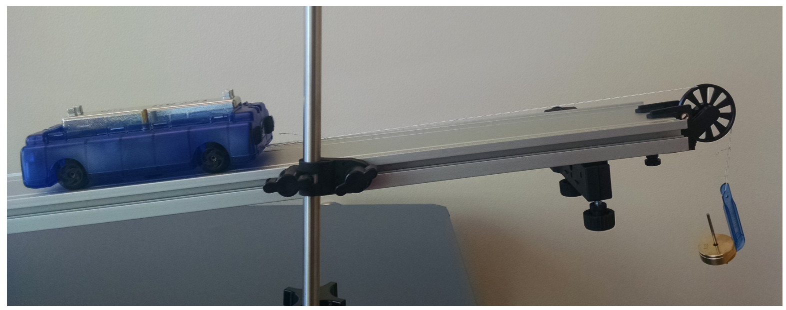
Section 3: Description of Demonstrations

The ten demonstrations described below each took took fewer than ten minutes of a class period. While none of them provided all the students with a physical hands-on experience, the demonstration itself was present in the classroom. The flipped classroom has at its core the ability to give students more practice with the material. A demonstration which amounted to additional lecture time was not desired but rather one that could replace a single calculation or provide an understanding of a calculation the students would have done instead. These demonstrations were designed to use the calculations students might have performed at the behest of a book to instead calculate something about objects physically in the classroom.

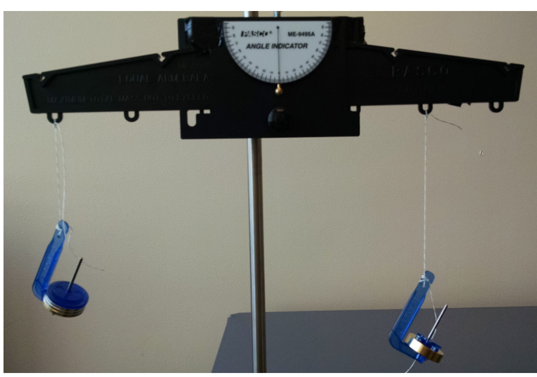
1) The first demonstration in class was extremely simple: a mass hanging from the tension protractor. One student was asked to read the dial on the protractor, and then the teams calculated the size of the hanging mass. The learning objectives here were to illustrate that mass and weight are not the same thing and to break the ice with the teammates. Class time spent: about 8 minutes.



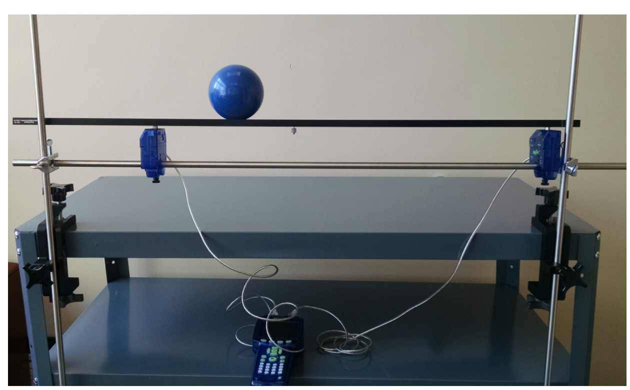
Two class periods later, the mass was strung between two tension protractors first on a single string where the mass could slide along the string and then on two strings where the lengths of the strings were fixed. This demonstration was designed to illustrate the difference in analysis between one and two strings. When one string was significantly shorter than the other, the difference in the tensions and angles indicated were also significant. The students were asked to calculate the tensions in the two strings based on the known mass and the angles off the protractor. Then they were able to read the tensions on the protractors to check their work. Class time spent: about 10 minutes.



2) and 3) The second and third demonstrations involved the particle equilibrium for a car on a track and took place on successive class days: draw the free-body diagram (FBD) for the car, and calculate how much weight would be needed to hold the car on the track neglecting friction. Before drawing the FBD, students were asked to discuss whether the car could be modeled as a particle or not. The original design of the equilibrium demonstration was for students to determine for themselves what givens they would need to calculate the particle equilibrium for the car and then to calculate the reaction at the track. Class time spent: about 8 minutes on the FBD and 8 minutes on the equilibrium problem.

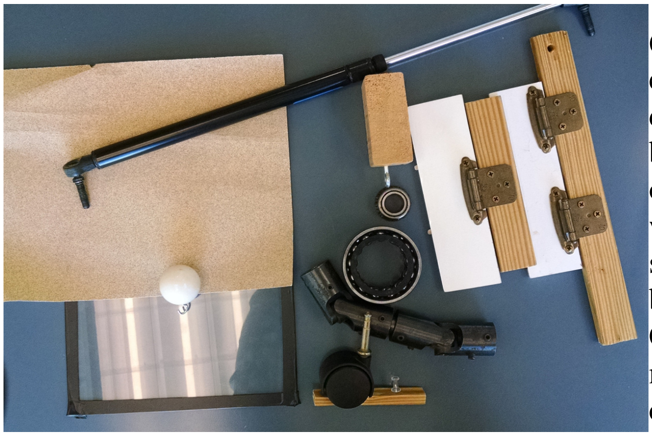


4) The fourth demonstration involved an equal arm balance with an angle indicator on it. As a demonstration of the law of the lever, students were asked to show that the weight times the distance on the left matched the weight times the distance on the right. Students were then shown an unequal (not level) condition and asked to calculate what would be necessary to add to return the system to equilibrium. Class time spent: about 5 minutes.

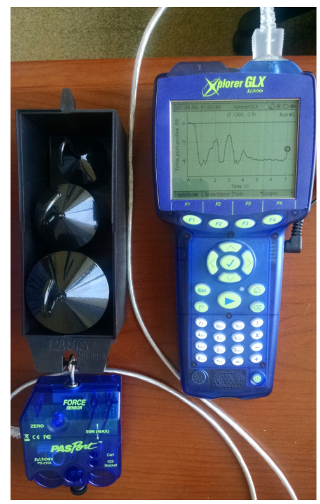


5) The next demonstration was developed by faculty at Clemson University in conjunction with Pasco. The learning objective was to understand simply-supported beams and demonstrate that the forces at each end would not each be half the weight of the ball but would sum to the weight of the ball. This was the first demonstration which used a data recorder. As the ball rolled from one end to the other, the force sensors indicated that the load had switched

from one sensor to the other. Students were not asked to calculate anything here. Class time spent: about 5 minutes.



6) Teaching three-dimensional constraints was expanded with a variety of props to expand on the discussion of three-dimensional FBDs for a rigid body. Demonstrations included items such as a ball on a piece of glass or sandpaper, boards attached with either one hinge or two hinges, a wheel on a surface or a rail, a thrust bearing and a journal bearing, a hydraulic cylinder, and a universal joint. Clickers were used so that students could predict the number of loads which would replace each constraint. Class time spent: 20 minutes.

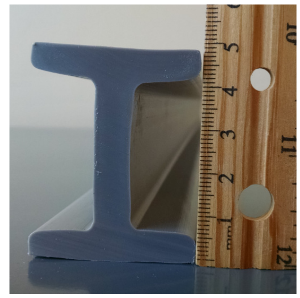


7) Students come to Statics having been taught that $F = \mu_s$*N; the students know this equation but must be taught when the friction force on a surface is equal to the friction coefficient times the normal force and when it isn't. The seventh demonstration was designed to measure the friction force F as a block begins to slide. The data recorder showed the students a specific graph of friction versus time. Students used the friction value when sliding occurred to calculate the coefficient of static friction μ_s. Class time spent: 10 minutes.

8) The eighth demonstration was for the definition of the angle of repose (the angle θ at which the car begins to slide down the track.) The car was fitted with a friction pad which lifted the wheels off the track. The track was lifted until the car slid down the track. Students used the angle to calculate the coefficient of static friction: $\tan \theta = \mu_s$. This demonstration led into the rolling friction the following day. Instead of using the friction pad, the car was inverted so that the plastic of the car slid on the track. The coefficient of static friction between the plastic of the car and the track was assumed to be similar to the coefficient of static friction between the plastic of the wheels and the track. The track was lifted until the car slid down the track which happened at about θ = 45 degrees. But when the car was right-side-up, it rolled down the hill at about θ = 1.5 degrees. This showed the students clearly that the rolling friction was different than the sliding friction. Student teams drew FBDs for the wheel and calculated the coefficient of rolling friction from the angle at which the car rolled down the hill. Class time spent: about 5 minutes for the demonstration with an additional 5 minutes for students to calculate the coefficient of rolling friction.

9) The oldest demonstration included here was an aluminum I-beam, 24-inches long with a 6x6-inch cross-section. (Web and flanges are 1/4 inch thick.) The I-beam was set on two chairs and a volunteer student stood in the middle of the beam holding a large axis system made of

PVC piping. The learning objective was to demonstrate how a force along the *y* axis combined with a distance along the *z* axis creates a moment along the *x* axis. Students calculated the area moment of inertia about the x and y axes. Class time spent: about 4 minutes to show and about 10 minutes to let the students calculate the area moments of inertia for the beam.



10) A flexible I-beam was available from Pasco though the item has since been discontinued. The beam is two feet long and can be bent fairly easily as an H-beam but bent only with difficulty as an I-beam. Students calculated the ratio of the area moments of inertia to determine how many times easier it was to bend the beam in one direction than in the other. Class time spent: about 2 minutes to show and 10 minutes for student calculations.

Section 4: Instructor Evaluation of Demonstrations

The first thing I learned as an instructor was that some considerable fumbling was inevitable at the beginning of this process of incorporating demonstrations. I believe that the presentations will become much more honed in the future.

1) The mass vs weight demonstration was surprisingly effective including an unexpected bit of learning: this demonstration turned out to be a fantastic illustration of the accuracy of measurements, of how one false measurement can propagate through the analysis, and about how important it was to think about the answer you calculated. Some groups calculated the mass at 5/9.8 = 0.510 kg. One group proudly told me that the mass must be 5000/9.81 = 509.68 g. Still others said 4.9/9.81 = 0.499 kg. The students compared their answers, and afterward we were able to talk about how well they knew the measurement. Had the protractor been zeroed? Did the company really send me a pre-packaged mass of 510 g? Students were profitably jarred by having the calculator answer not be perfect. This demonstration illustrated the importance of understanding accuracy and significant digits, of differentiating mass and weight, and of thinking through your answer.

The second demonstration with the tension protractors was less effective. While the calculation was straightforward, the students already seemed to have a good understanding of tensions in ropes so that little was gained in seeing it. Where the mass vs. weight seemed to tweak their own assumptions, calculating the particle equilibrium for the mass between two strings seemed to feel like busy work. This experiment was repeated in Spring 2016 to much better effect: students were given the values so that the problem ended up being very much more equivalent to a book problem. This seemed to allow the students to focus on equilibrium. In the future this could be profitably turned into a virtual demonstration for use outside of class time to allow the students to play around with values.

2) The FBD for the car did not flow easily during class: students were willing for me to say, “No, I cannot model this as a particle” or “Yes, I can model it as a particle,” but they were dissatisfied by the answer of “Both, depending on what you want to know.” More work must be done here to frame this discussion. Though I certainly learned about how the majority of my students think, they did not expand their understanding of modeling a system. My students seem to have a difficult time grasping the concept that different FBDs can be used for the same situation based on what information is desired. They were unhappy with having more than one right answer to the question.

The FBD drawing for the car has been repeated once in Spring 2016. Students were simply asked to draw the FBD with no discussion of whether the car could be modeled as a particle. Few students struggled to produce the FBD. But after the FBD was drawn we did discuss the assumptions which were made. This seemed to be an easier introduction into modeling a system: let the students make the assumptions and then point them out rather than asking the students what assumptions they needed to make.

3) The next day I brought the track back into class. Originally I wanted the students to ask for the mass of the car, for the angle of the track, etc. I had hoped that they were at a point where they could start understanding what values were required. The students in my class ended up not being adequately prepared to understand that I wanted them to determine the values to ask for. We ended up with an uncomfortable scene of me standing there waiting for them to ask me for a value and with them waiting to be told what to do. In the future this demonstration will be rolled back to ask the students to calculate the angle of the track based on the given mass of the car and mass on the hanging rack. Perhaps after several semesters of this approach I can revisit what problem setup I would need to use for the students to explore being able to take their own measurements or as above come at the assumptions after the fact. The best I can say for this demonstration in Fall 2015 is that it didn't amount to yet another problem from the book. In future semesters it may be better to introduce determining the needed values and the multiple answers to a question later in the semester.

4) The law of the lever is another concept which is simple to demonstrate, but also simple to understand. The students were able to finish the calculations with ease.

5) The Force Distribution System demonstration was not designed by me; this demonstration was included principally as a control to calibrate student reception to the demonstrations: a demonstration which is sold as-is was considered to be well-vetted. If the students liked this demonstration and disliked the others, it might be due to the poor design of the other demonstrations. Anecdotally I felt that fewer students this semester forgot to use the sum of the moments equation for a simply supported beam.

6) The three-dimensional FBD demonstrations were developed about two years ago for use in my class. This demonstration starts at a big advantage over the others discussed here in that it is designed to demonstrate a concept which students have more difficulty with than, say, particle equilibrium. It is useful to have a physical object to show the students when talking about removing a constraint and replacing it with a set of loads.

7) The calculation of the coefficient of sliding friction demonstrated that the value of friction changed from zero to a maximum value. Students could see the graph as I pulled the block. This demonstration captured data in class, used that data to calculate something, and debunked a common misconception for students. These three elements seem to me to be the hallmark of an excellent demonstration. For the students in the front row, this demo fulfilled its promise. It was difficult to see for the students in the back.

8) The calculations for the angle of repose and the coefficient of rolling friction are not complicated. Student difficulties arise principally from understanding what it is that they are working with. In that respect the simplicity of the calculations is actually a liability. Seeing the car slide down the hill at 45 degrees but roll down the hill at 1.5 degrees was so very glaring a difference that students knew viscerally that rolling friction and sliding friction were different. This certainty in their understanding

allowed me to explain how the concepts were related more easily than in past semesters.

9) Students usually come to Statics with a vague idea that the I-beam should be right-side-up, that is not as an H-beam. But they have no idea why as a general rule. Having a classmate stand on the beam was a comic way to get the students to think through the axes and why you would want to move material away from the axis of rotation.

10) Similarly, the flexible I-beam allowed me to show explicitly that the same beam could be bent more in one direction than in another. The visual evidence was much more convincing for students than my statement of the case. Students went on to calculate the ratio of I_y to I_x and had something physical that they had seen to work from.

My overall impressions were that instructors need practice (not everything goes well the first time), that students need a way to see the demonstration from the back of a full class, and that while simple demonstrations are useful I need to find a ways to focus on demonstrating the harder concepts in Statics (more like the I-beams and fewer like the law of the lever.)

Section 5: Student Survey Results

Students were surveyed mid-way through the semester to assess their opinions of the demonstrations. 239 students filled in the online survey (response rate = 66.2%). The survey was simple: what section are you in, how much class time should we spend on such things, and how did you like each of the individual demonstrations. Student results for the class time which should be spent on demonstrations are shown in Table 1.

Table 1: Percentage of Class Time

What percentage of class time (excluding the 15% that I talk) would you prefer to have used for demos?	
a. 0% demo, 85% working book problems with your team	12 (5.0%)
b. 20% demo (maybe one or two per week), 75% working book problems with your team	141 (59.0%)
c. 40% demo (one every class day), 55% working book problems with your team	73 (30.5%)
d. 60% demo (multiples every class day), 35% working book problems with your team	12 (5.0%)
e. 80% demo (almost all of class), 5% working book problems with your team	1 (0.4%)

The vast majority of students (almost 90%) expressed the preference that demonstrations happen at a rate between one per week and one per day. Only 5% of the students seemed to think these demonstrations should be avoided. Five of the twelve students who said that the demonstrations should not be used complained that they were in the back of the classroom and could not see them. This indictment could be avoided with better camera work in the future or at the very least better prior pictures.

Students were also asked to rate the demonstrations (results in Table 2). Students who did not respond were lumped together with those who selected NA. An overall approval rating was calculated by adding the number of 4 and 3 ratings and dividing this sum by the number of 2 and 1 ratings.

Table 2: Student Ratings for Demonstrations

Some of the demonstrations I've used in class this year are listed below. Rate these demos as they helped you learn the material. **1 = “Did not increase my understanding of the material at all.”** **to** **4 = “Increased my understanding significantly.”** **NA = demonstrations you were not in class to see or don't remember**						
Demonstrations	4	3	2	1	NA	Overall
1) Tension Protractors	20 (8.4%)	84 (35.1%)	97 (40.6%)	24 (10%)	14 (5.9%)	0.86
2) Equilibrium for Car	44 (18.4%)	104 (43.5%)	62 (25.9%)	21 (8.8%)	8 (3.3%)	1.78
3) FBD for Car	48 (20.1%)	91 (38.1%)	60 (25.1%)	32 (13.4%)	8 (3.3%)	1.51
4) Law of the Lever	62 (25.9%)	84 (35.1%)	56 (23.4%)	19 (7.9%)	18 (7.5%)	1.95
5) Force Distribution System	54 (22.6%)	74 (31%)	65 (27.2%)	27 (11.3%)	19 (7.9%)	1.39
6) 3D FBD Demonstrations	93 (38.9%)	65 (27.2%)	40 (16.7%)	21 (8.8%)	20 (8.4%)	2.59
7) Friction Coefficient Measurement	76 (31.8%)	80 (33.5%)	57 (23.8%)	20 (8.4%)	6 (2.5%)	2.03
8) Rolling Friction vs Sliding	63 (26.4%)	83 (34.7%)	54 (22.6%)	31 (13%)	8 (3.3%)	1.72
9) Aluminum I-beam	97 (40.6%)	66 (27.6%)	43 (18%)	21 (8.8%)	12 (5%)	2.55
10) Flexible I-beam	84 (35.1%)	88 (36.8%)	44 (18.4%)	14 (5.9%)	9 (3.8%)	2.97

These survey results clearly indicate that students felt the demonstrations helped them learn the material. Students chose 4 or 3 at nearly twice the rate that they chose 2 or 1. Some demonstrations were clearly more helpful than others, especially those which corresponded to more difficult concepts. The student ratings for the Force Distribution System demonstration developed at Clemson were very much in line with the new demonstrations.

The students were asked to rate the effect these demonstrations had on their learning. Some of the concepts like the equilibrium for a car on a track are clearly not as complicated to understand as why the moment of inertia for a beam is higher in one direction than in another. This may have fed into the high ratings for the I-beam demonstrations. One student remarked, “For topics like moments of inertia, the demonstrations were particularly useful since the topics were generally newer ideas to grasp.”

Student comments indicated frustrations with seeing from the back of the class and with the fast pace of the demonstrations. Of note: even the demonstrations which I found to be particularly ineffective during class did not rate terribly in the student scores. From this I concluded that the demonstrations were indeed helpful for students trying to visualize what concepts we were talking about.

Interestingly, two of the three highest-rated demonstrations were implemented first and have been used many times; part of the high ratings here may be that the instructional patter which went with this demonstration has been honed over many presentations. All the other demonstrations were new this semester. The three highest rated demonstrations corresponded to the three hardest concepts. Students clearly felt that the demos helped here.

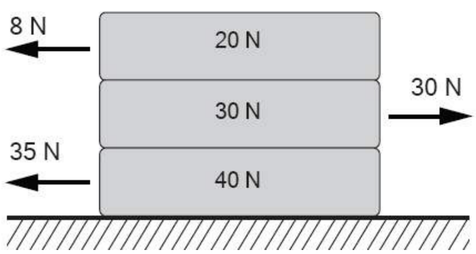
This survey was taken approximately three-fourths of the way through the semester rather than after each individual demonstration, so some demonstrations were much fresher in the minds of the students.

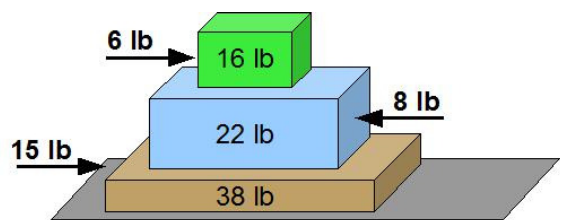
While this could have introduced some bias, the number of students who indicated that they did not remember the demo (NA) did not increase as the demonstrations became longer in the past.

Section 5: Student Exam Comparisons

In a perfect world, clear increases in student performance could be shown on exam questions from before the demonstrations to after the demonstrations were implemented. This proved to be very difficult for several reasons: first, exams were produced to test all the material in the class not just the understanding of specific topics. Second, these demonstrations did not necessarily illustrate the most important concepts in Statics but sometimes only the most likely to be misunderstood; the exams were designed to test the more important concepts. Third, the exams are necessarily limited in how many items can be tested. And last, as some of the demonstrations have developed over many years, it is complicated to define before and after.

There was one test question where a before-and-after comparison could be made. In fall 2014 and fall 2015, students were asked to determine the horizontal friction force on the lower face for the top block in a stack of blocks.





This question on the left was originally produced by Stief and Dantzler as one of the concept inventory questions and was used on my Fall 2015 Final Exam.[22] The problem on the right was essentially identical and appeared on my Fall 2014 Final Exam. This problem required students to understand that friction could be any value between zero and μ_s*N, a point we illustrated with real-time data in demonstration 7.

	2014, before demonstration (N = 333)	2015, after demonstration (N = 361)
correctly identified force in x	43.54%	53.19%
used F = μ_s*N	32.43%	34.07%
other	24.02%	12.73%

Though essentially the same number of students had a knee-jerk reaction that the friction force must be μ_s*N, more students correctly identified the sum of the forces horizontally as the important point here. Though this is a weak result, it was encouraging.

Section 6: Conclusions and Future Research

Students clearly liked having the demonstrations in class. The time required was modest and did not unduly impact the other activities which would have occurred in class.

As my own experience with the data recorder increases, I should be able to help the students move more speedily from taking the data to working a problem with it. This research clearly shows that a sizable majority of students like having physical demonstrations in class.

Students' comments indicated a desire to have student groups calculate something specific from the demonstration. A next step in working with these demonstrations would be to develop more specific “book-type” problems with calculations collected directly in class. The pages in the course pack could be adjusted to indicate clearly what data will be provided in class.

It is not possible with the data available to assess whether learning has actually increased. In the future, more exam questions from before and after a demonstration is implemented should be collected to ascertain whether students' ability to grasp and retain the material is increased by seeing a physical demonstration.

Several times students learned something other than what had been planned for a demonstration, but this was classed as a success. These occasions should be grasped and future implementations adjusted accordingly. Even off-the-shelf demonstrations will need to be tailored and allowed to evolve over time with each instructor.

Specific demonstrations for hydrostatic pressure demonstration and mass moment of inertia should be developed as these are some of the more difficult-to-grasp concepts. As individual demonstrations are added, it would be helpful to compare exam questions on that concept from before and after the demonstration is added.

A student who is trying to learn a new concept must draw on his understanding of all the concepts which went before. In a class like Statics which builds on itself as well as on physics and mathematics, the challenge is to make the basic concept so well understood that the next concept in line can be managed without tripping over the basic ideas. These demonstrations seemed to firm up the basic concepts for students. Though this research does not measure an increase in learning of any specific thing, the more advanced concepts such as rolling friction seemed more accessible to the students indicating that the basic ideas of friction were more deeply comprehended. Though demonstrating the more advanced concepts is a future goal, the success of this project lies in providing students another way of understanding those basic concepts.

References

[1] Pasco Force Distribution System http://www.pasco.com/prodCompare/force-distribution-system/index.cfm

[2] Ohland, M.W., E.A. Stephan, and B.L. Sill, “Adapting Engineering Laboratories to Enhance Learning using Real-Time Sensors in Freshman Programs,” Proc. Amer. Soc. Eng. Ed., Portland, Oregon, June 2005.

[3] Bishop, Jacob Lowell and Verleger, Matthew A, “The Flipped Classroom: A Survey of the Research,” Proceedings of the 2013 American Society for Engineering Education Annual Conference & Exposition, Atlanta, GA, June 2013.

[4] Yufeng Hu, P. E., Javier Martin Montefort, and Edmund Tsang. "An Innovative Redesign of Statics: Approach and Lessons Learned," Proceedings of the 2015 American Society for Engineering Education Annual Conference & Exposition, Seattle, WA, June 2015.

[5] Papadopoulos C, Santiago-Román A. “Implementing an Inverted Classroom Model in Engineering Statics: Initial Results.” Proceedings of the ASEE Annual Conference & Exposition, Louisville, KY, June, 2010.

[6] Holdhusen, M. “A 'Flipped' Statics Classroom," Proceedings of the 2015 American Society for Engineering Education Annual Conference & Exposition, Seattle, WA, June 2015.

7 Howard, A. K. T., “Enhancing Student Engagement in Engineering Statics with Online Tools,” ASME 2010 International Mechanical Engineering Congress & Exposition, Vancouver, BC, Canada, November 12-18, 2010.

8 Howard, A. K. T., “Instructional Videos -- Three Kinds of Videos to Meet Different Student Needs,” Teaching and Learning Symposium Poster Session, NCSU, April 4, 2012. <https://people.engr.ncsu.edu/akhowar5/videooptions/images/Instructional_Videos.pdf>.

9 Howard, Anna. "NCSU MAE 206 Statics." YouTube. YouTube, 8 May 2015. Web. 12 Nov. 2015. <https://www.youtube.com/playlist?list=PLDcYwd3-RVr_xwJIUGusj4LNz8yCPVEc6>.

10 Jensen, M., and Howard, A.K.T. “Flipped Classes: Do Instructors Need to Reinvent the Wheel When it Comes to Course Content?” Proceedings of the 2015 American Society for Engineering Education Annual Conference & Exposition, Seattle, WA, June 2015.

11 Howard, A.K.T., “Not all Video is Good Video” DELTA Summer Shorts. NCSU, Raleigh. Aug. 2015. <https://people.engr.ncsu.edu/akhowar5/goodvideo/presentation.pdf>.

12 Khan, Salman. "Salman Khan: Let's use video to reinvent education." TED. com. 2011.

13 "Khan Academy." Khan Academy. Web. 15 Jan. 2015. https://www.khanacademy.org/about#faq.

14 Beichner, Robert J., and Jeffrey M. Saul. "Introduction to the SCALE-UP (student-centered activities for large enrollment undergraduate programs) project." Proceedings of the International School of Physics “Enrico Fermi,” Varenna, Italy, 2003.

15 Lucke, T, and Killen, P., “Using Hands-on Models to Improve Student Learning Outcomes in Statics.” Proceedings of the Australian Association of Engineering Education, Melbourne, AU, 2012.

16 Dong, K. (2006, June). “Making Statics a Friend for Life.” Proceedings of the 2006 ASEE Annual Conference. Chicago, IL.

17 Dollar, A., & Steif, P. (2002, June), Understanding Internal Loading Through Hands On Experiences Paper presented at 2002 Annual Conference, Montreal, Canada. https://peer.asee.org/10420

18 Ramos, Joshua D. Hands-on online: towards experiential product design education with online resources. Diss. Massachusetts Institute of Technology, 2013.

19 Steif PS, Dollar A. “Web-Based Statics Course Used in an Inverted Classroom.” Proceedings of the ASEE Annual Conference & Exposition, Austin, Texas, 2009.

20 "McGraw-Hill Connect." Connect. McGraw Hill, n.d. Web. 12 Nov. 2015. <http://connect.customer.mheducation.com/about/>.

21 Steif, Paul. "Open Learning Initiative." Engineering Statics. Carnegie Mellon University, 2015. Web. <http://oli.cmu.edu/courses/free-open/engineering-statics-course-details/>.

22 Steif, Paul S., and John A. Dantzler. "A statics concept inventory: Development and psychometric analysis." Journal of Engineering Education 94.4 (2005): 363-371.

Anna K. T. Howard

Anna Howard received her Ph.D. in Aerospace Engineering from Penn State University studying the aeromechanical stability of tiltrotors. She is currently a Teaching Associate Professor in the Mechanical and Aerospace Engineering Department at NCSU where she serves as the course coordinator and primary instructor for Engineering Statics and has lead the large course redesign project for MAE 206. Her redesign aimed to combine online materials with in-class working groups in a flipped format with the goals of providing more "just-in-time" learning opportunities and reducing drop/withdraw/fail rates as much as possible. Through Engineering Online, Dr. Howard also teaches Statics at Havelock Community College, the University of North Carolina at Wilmington, and the mechatronics program at the University of North Carolina at Asheville. Dr. Howard also occasionally teaches Aerodynamics of V/STOL Aircraft. More info: https://www.youtube.com/watch?v=wmtLj5lkCCg