Flipped Classroom – Ten Years Later

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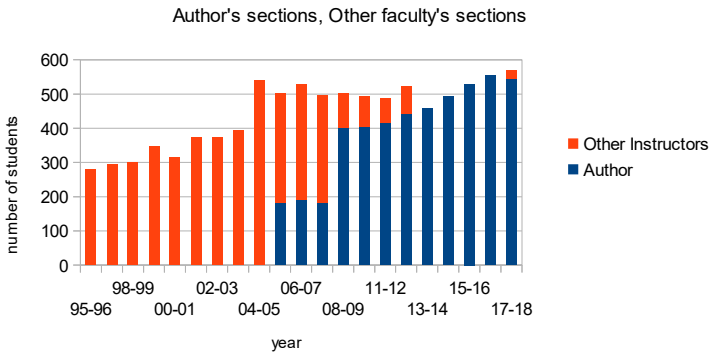
Abstract: The literature is full of examples of people who have flipped their classes. Fewer papers address what happens years later. Spring 2019 marks ten spring semesters since Engineering Statics in the Mechanical and Aerospace Engineering Department at North Carolina State University was first run as a flipped class. In this paper, I will talk about the years from 2007 to 2013 during which time the course was redesigned. I will catalog the main research findings from the initial flipped class as well as the changes made in the years since then. I will describe the current course as it has developed over the ten years since it was originally flipped and the learning objects used in it. My subjective experience from the redesign is included along with comments from some of the students.

Introduction:

Between Fall 2000 and Fall 2007 twenty-three different professors taught sections Engineering Statics in Mechanical and Aerospace Engineering with no common syllabus or common assignments. Drop, withdraw, fail (DWF) rates varied from 2% to 78% – students picked their course section based on grade expectation. Over the years between 2005 and 2013, I taught more and more of the offered sections, effectively reducing course drift and enforcing a common set of learning objectives.

Figure 1. Total Enrollment in Statics as taught by Howard



The redesign process for Statics in Mechanical and Aerospace Engineering began in 2006 with a one-week short course for teaching with technology hosted by NC State's Distance Education and Learning Technology Applications (DELTA) and with the Redesign Alliance conference held in Orlando in 2008.[1] These events codified for me the importance that the pedagogy must lead any technology solution and lead to an overall redesign plan.

The redesign process included three phases from lecture to flipped class. This paper will discuss the three phases of redesign for Statics starting with an archetypal lecture section in fall 2005 and proceeding through the first flipped class in spring 2010 and the final data gathering in fall 2013. I will also discuss the ten spring semesters worth of flipped classes and how the class has changed in that time.

Statics as a critical-path course with a high drop-withdraw-fail (DWF) rate. The initial goals included lowering that DWF rate while improving the student learning if possible. For analysis purposes three phases were defined: Phase 1 classes were pure lecture. Phase 2 included more online materials and computerized exams.[2] Phase 3 classes were fully flipped. Note that the current class differs from Phase 3 in ways discussed below.

Learning materials were introduced as they became available. Each year was a bit different than the others, so these phases are not homogeneous throughout their years. We were careful to separate the kinds of classes where there was overlap between phase 2 and 3.

Table 1. Phases in Redesign of MAE 206, Engineering Statics at NC State University

Phase 1	Phase 2	Phase 3 (overlaps with Phase 2)
Fall 2005 – Spring 2008	Fall 2008 – Fall 2012	Spring 2010 – Fall 2013
Class time: lecture	Class time: lecture	Class time: student problem-solving
Exams: on paper	Exams: in Moodle	Exams: in Moodle
Basic review material available.	Livescribe pen examples MediaSite lecture videos Clickers in class [3]	Short concept videos, captioned, along with Mediasite lectures

Initial Study:

The initial study question was whether my Phase 1 class had results similar to other instructors' results. It was important to establish as a baseline that my teaching wasn't sufficiently below average so that any improvement in student outcomes could have been either the students' improvements or my own. Student results from two tenured faculty with significant experience teaching Statics (each had taught Statics five or more times in the last five years) were compared with student results for my Phase 1 lectures [4]. Combining my students with the students who studied under the other two faculty provided a population of 1145 students. The model considered only students' first attempt at Statics.

Though the syllabus was common between these three faculty, the assignments and exams were not. As it was impossible to compare the student performance in Statics, these students were tracked into the follow-on courses of Dynamics and Solid Mechanics. The statistical model included ethnicity, gender, instructor, GPA at enrollment in Statics, and the length of time between Statics and the follow-on course.

No statistically significant difference was observed between the students in any of the three Statics presentations.[4] This study allowed me to be confident that the students in my lecture learned as much as the students in other lecture sections. The students from my lecture sections therefore form a reasonable baseline to compare with my students from later redesigned sections. This initial study also provided confidence that results from the changes in how the class was run might be transferable to other instructors and potentially other classes as well.

Comparing Redesign Phases:

Starting in 2008 I began developing and posting online materials in our campus learning management system. Content at that time was divided into 28 learning modules that each included:

- an introduction including a list of main points
- example problems
- practice quizzes. (Online quizzes were part of the semester grade; students received immediate feedback and could take the same quiz three times.)
- message boards: student-to-instructor and student-to-student

Between 2009 and 2013 a complete set of written content was developed and added including:

- web pages with text
- embedded videos of worked example problems
- embedded short concept videos.

During Summer 2013 these course notes were expanded to include thought questions so students could assess their own learning.

Beginning with Phase 2, Matlab was introduced to the students at several points over the semester to ensure that each student could use Matlab as it has become something of an industry standard. In the early part of my teaching, NC State had no course to teach Matlab. At the current time over 67% of my students have taken or are currently taking a course in Matlab when they take Statics. The content for Matlab in Statics has been dialed back, but the basics of Matlab are still presented each semester. The final project requires students to design a space truss and test it using a provided Matlab program.

Table 2: Statics Sections taught by Author with Enrollments between Fall 2008 and Fall 2013

	Section 1	Section 2	Section 3
Fall 2008	Phase 2 (54)	Phase 2 (100)	Phase 2 (103)
Spring 2009	Phase 2 (69)	Phase 2 (76)	
Fall 2009	Phase 2 (56)	Phase 2 (104)	Phase 2 (109)
Spring 2010	Phase 3 (65)	Phase 2 (71)	
Fall 2010	Phase 2 (54)	Phase 2 (96)	
Spring 2011	Phase 2 (53)	Phase 3 (114)	
Fall 2011	Phase 2 (97)	Phase 2 (127)	Phase 2 (59)
Spring 2012	Phase 2 (47)	Phase 2 (87)	
Fall 2012	Phase 2 (73)	Phase 2 (70)	Phase 3 (110)
Spring 2013	Phase 3 (50)	Phase 3 (83)	
Fall 2013	Phase 3 (94)	Phase 3 (107)	Phase 3 (83)

* Highlighted sections are flipped classes.

Review modules with similar content structure to the class materials were available to help students with vectors and with trigonometry. Each topic was explained and shown with examples of where such a topic would be used in Statics. Optional practice quizzes helped students feel more confident in their knowledge. (Anecdotal comments indicated that returning and other nontraditional students found these modules especially useful.) TurningPoint clickers were also used in both Phase 2 and Phase 3 classrooms.

The big difference between Phase 2 and Phase 3 was the use of class time. In Phase 2 I lectured for the 50-minute classes and made an attempt to make those lectures interactive with clickers. Students in Phase 3 had no in-class lectures. They were charged with watching a 50-minute Mediasite video of the lecture from a previous semester before class. During class students worked in groups of three solving textbook problems. Phase 3 flipped classes also differed from previous phases by including undergraduate or graduate learning assistants in the classroom; the ratio of student to expert was kept at not more than 40-to-1. The setup for these classes was inspired by the Scale-Up model [5].

By Fall 2008 I taught all the sections of Statics in the MAE department. This situation made testing the flipped class ideal for an apples-to-apples comparison. In the three semesters Spring 2010, Spring 2011, and Fall 2012, one section was flipped with the other sections kept as lecture-based. Students were not informed before the semester that some classes would be flipped.

The 2011-2012 year did not have any flipped classes because no funding was available to hire extra undergraduates or graduate students to be in the classroom. Beginning in Spring 2013 all of the author's classes have been flipped.

A new statistical model was built to compare the design phases. The population of students included full-time, on-campus undergraduates who took Statics for the first time with me between Fall 2005 and Fall 2013. For students who had to retake the class, only the first attempt was included. The population included 2,412 undergraduate students. [6]

The study investigated whether student performance was improved, whether DWF rates had gone down, and whether the phase of Statics taken had any effect on student outcomes in Dynamics. Grades were binned to neglect pluses and minuses: for example, B+, B, and B- grades were considered equivalent.

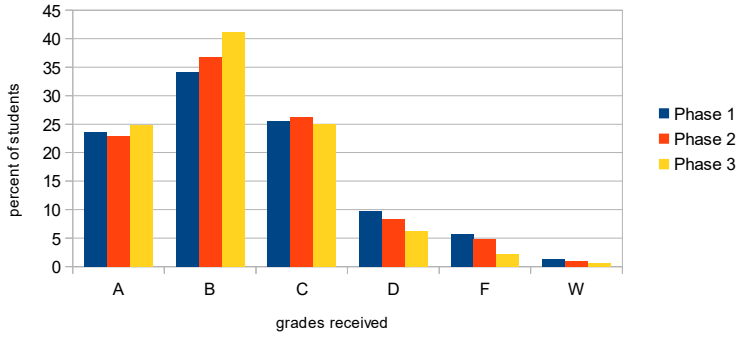
Performance in Statics by Phase:

Grades in Statics improved over the phases. The most notable difference is between Phase 3 as compared to Phase 1 – the flipped class exceeded the performance in the lecture class. (see Figure 2) The proportion of B grades increased by 21%, the proportion of D grades decreased by 36%, and the proportion of F grades decreased by 62%.

A Pearson Chi^2 Test of Independence showed strong evidence that an association does exist between students' final grades in Statics and the design phase they experienced (X^2 [10, n=2,412] = 20.84, p = 0.016). The number of students in Phase 3 who earned a B is significantly higher ($z=2.31$, $p<.05$) and the number who failed is significantly lower ($z=-3.10$, $p<.01$) than we would

expect if the distribution of final grades were independent of the course design.

Figure 2. Statics Grades Distributions by Redesign Phase



Overall the DWF rate dropped from 16.8% in Phase 1 to 9% in Phase 3; out of the 641 students in this study who took the flipped class, these rates suggest that almost 50 students passed Statics who would not have at the Phase 1 rates. The Pearson Chi^2 test showed a weak but statistically significant relationship between the proportion of students with a DWF result and the course design used ($X^2[2] = 15.76$, $p<.001$; Goodman and Kruskal's gamma test $\gamma=-.11$, $p<.001$). Residuals showed significantly more DWF's in Phase 1 ($p<.01$) and fewer in Phase 3 ($p<.001$) than we would expect if the DWF rates were independent of course design.

Figure 3. Statics Drop-Withdraw-Fail Rate over Time

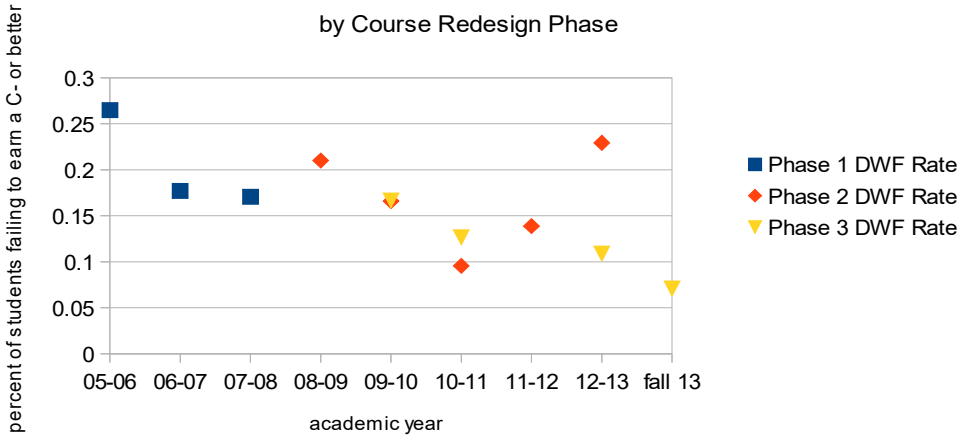


Figure 3 shows the DWF rates for each phase over the years. The most unexpected data point was during the 2012-2013 year when Phase 2 students had a much higher DWF rate than the previous students in Phase 2. Each semester exams change, homeworks change, graders change. So each semester a slightly different curve emerges (rarely more than 1 point for the average.) This semester is also the first time that a big percentage of the students were in flipped classes. 63% of all the students included took the flipped class. I hypothesize that these students blew the curve for their compatriots who were in a lecture class.

Apples-to-Apples:

In three of the semesters listed above, I taught a lecture section at the same time as a flipped section. Students in the same semester completed the same assignments and took the same assessments so that only the in-class experience and the preparation for class was different. The apples-to-apples comparisons were limited by the smaller numbers of students to compare even having combined all three semesters. Additionally, the pass or didn't-pass categories limit the use of analyses such as least squares regression.

Table 3: Course Completion in Apples-to-apples Sections, 2010-2012

	Phase 2 DWF (N)	Phase 3 DWF (N)
Spring 10	22.0% (11 of 50)	14.3% (8 of 56)
Spring 11	10.3% (4 of 39)	11.2% (10 of 89)
Fall 12	18.7% (25 of 134)	8.7% (9 of 104)

We applied Bonferroni-adjusted Wald tests of the individual regression coefficients which allowed us to conclude that the odds of failing to complete the course in a Phase 3 section are significantly lower than the odds associated with Phase 1 (OR = 0.48, 95% CI [0.32, 0.71]; $z = -3.61$, $p < .001$) and are also significantly lower than the odds in a Phase 2 section (OR = 0.56, 95% CI [0.37, 0.85]; $z = -2.71$, $p = .021$).[6]

We concluded that Phase 2 students are 2% less likely to drop, withdraw, or fail than students in Phase 1. Phase 3 students are 8% less likely than students in Phase 1 to earn a DWF. (One additional finding was that students taking Statics in the spring are an average of 6% more likely to earn a D, F, or W than students in fall.)

Knowledge Retention:

The last piece was to determine whether the phase of the redesign students encountered affected their performance in follow-on classes or not. Initial results suggested that there was an effect[4], but that that effect decreased as the time gap between Statics and the next course increased. The initial data also showed a higher influence on Dynamics than on Solids. In our final study we considered the question of whether the phase students experienced in Statics affected whether or not they were able to pass Dynamics in a single attempt. All students from the 2,412 student sample who passed Statics on their first attempt and then went on to take Dynamics between spring 2006 and summer 2015 were included resulting in a sample size of 1,706 students.

Table 4. Summary of Course Attempts in Dynamics by Redesign Phase Experienced in Statics

	Attempted Dynamics once	Attempted Dynamics twice	Attempted Dynamics three times
Phase 1	87.8% (323 of 368)	11.7% (43 of 368)	0.54% (2 of 368)
Phase 2	91.0% (784 of 862)	8.5% (73 of 862)	0.58% (5 of 862)
Phase 3	94.3% (449 of 476)	5.3% (25 of 476)	0.42% (2 of 476)

The number of attempts in Dynamics dropped as the redesign of Statics progressed: the percent of students who needed to take Dynamics more than once dropped by more than half, a statistically significant difference at p=.001. Compared to the odds for a student who took the Phase 1 version of Statics, the odds of repeating Dynamics are between 74% and 29% lower for a student who completed the flipped course.

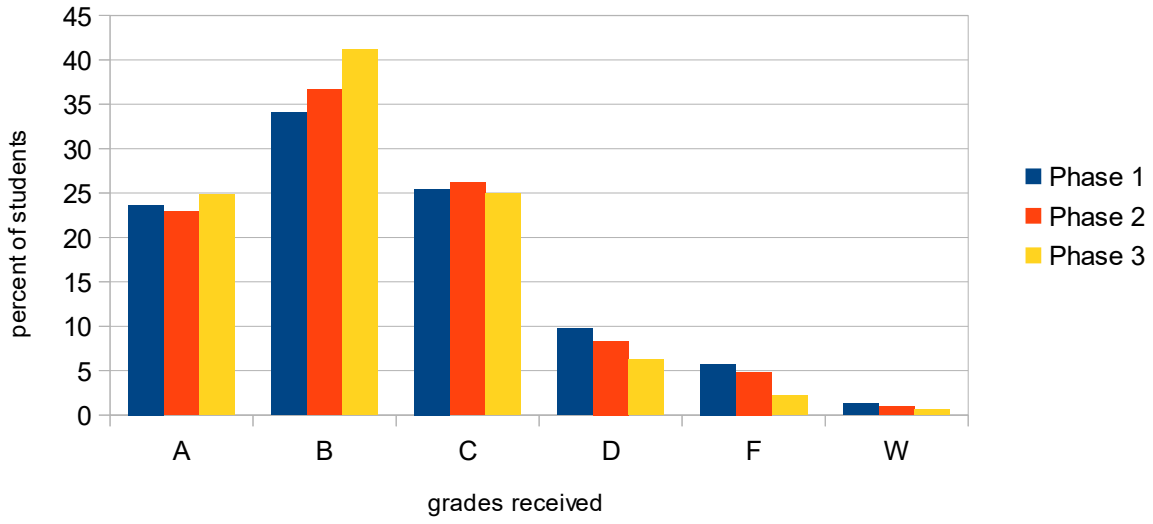
In addition to the number of times a student had to take Dynamics, the Chi^2 test indicated that the distribution of final grades in Dynamics was affected by the Statics phase ($X^2[10]=40.55$, $p<.001$). Students who took the lecture version earned A's on their first attempt at Dynamics significantly less often (and C's, D's, and F's significantly more often) than students who took the flipped version of Statics.

Table 5. Student Grades in Dynamics by Redesign Phase Experienced in Statics (N)

	A	B	C	D	F	W
Phase 1	19.1% (68)	32.3% (115)	32.0% (114)	10.4% (37)	5.9% (21)	0.28% (1)
Phase 2	28.2% (238)	35.5% (300)	25.4% (215)	7.9% (67)	2.5% (21)	0.47% (4)
Phase 3	28.2% (133)	41.7% (197)	21.6% (102)	5.7% (27)	2.1% (10)	0.64% (3)

More students earned A's and B's and fewer students earned C's, D's, and F's. The null hypothesis is that the phase experienced in Statics shouldn't matter once students are out of Statics and are taking Dynamics. The frequency of grades differs significantly from this hypothesis in seven different grades in the figure below.

Figure 5. Dynamics Grades by Redesign Phase in Statics



* indicates values which differ significantly from the expected frequency under the null hypothesis

Changes Made to Class Time over Ten Years:

After the studies above, I will never teach a lecture version of Statics again. I am convinced that students learn better and retain the information longer. Beyond that, the flipped class allows me to help the students one-on-three or even one-on-one. The opportunities to hear a student struggle and come to the understanding right in front of you continue to make teaching this class a continued joy.

Since 2013 when the studies discussed above concluded, some additional changes have been made in the flipped classroom. For example, students are now led through the problems worked in class rather than having each group work independently. This allows me to explain individual choke-points in the problem as students get to them. The 2-ft x 3-ft white boards with groups of 3 students (with only one marker and one eraser) have been retained, but the groups are encouraged to work at a set pace rather than at their own pace. As I walk around the classroom, I can see whether students have gotten to the next point I want to make; when a bunch of students get to that spot, I will stop all the groups to explain the misconception or the next step.

The 50-minute videos have been gradually replaced with short concept videos which average 5.5 minutes each; these videos are much preferred by students. The first 4 short videos were produced in Spring 2012 and were well-received by students. The current library includes 73 videos [7]. Some class periods include as many as four or five videos while some class periods have no additional videos for students to watch before class [8]. Students have found these short videos significantly easier to digest than the 50-minute lectures. Students routinely list these videos as the most important tool in their learning in Statics. These videos are posted at YouTube and have been used by faculty and students around the world. [9]

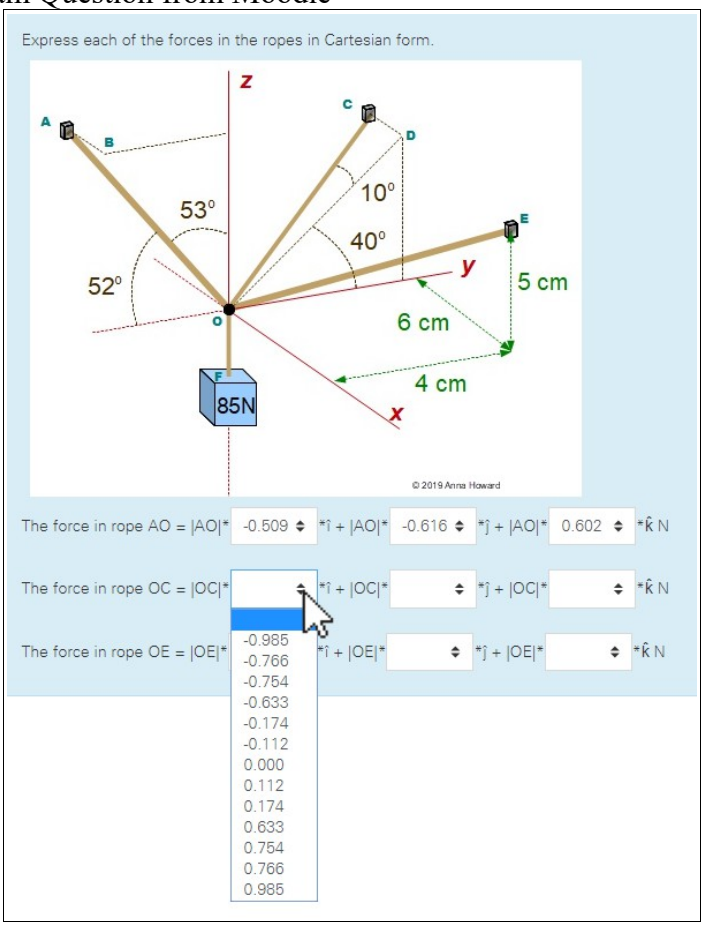
The original flipped class only had students working problems out of the book. Beginning in Fall 2015 in-class demonstrations replaced some of the book problems. [10] These demonstrations illustrate common misconceptions and use class time for more than just book problems. Since 2013 I've produced a course pack which students were required to buy. [11] The course pack initially included the slides but was modified to include written versions of the problems to be worked in class and pictures of the demonstrations done in class. The course pack also includes skeleton notes for the textbook readings. [12] The solution to these skeleton notes from the text is provided to the students as a review before each midterm.

The student-to-expert ratio of 40-to-1 has been sufficient for many semesters now with one big exception: the class day where two-dimensional rigid-body free-body diagrams (FBD) are taught needs additional help in the classroom so that every group of students gets every FBD checked off. The classroom help was originally undergraduate learning assistants who had taken Statics with the author previously. Between Fall 2013 and Spring 2019 the in-class help has been graduate students in the department, partly to help fund the graduate program. Starting in Fall 2019 the plan will be to go back to undergraduate help: the Statics experience is fresher for undergrads than it is for graduate students. Undergrads can often explain concepts to their peers better than the graduate students can.

Exams are given in Moodle, our current campus learning management system. An example

problem is shown in Figure 6. Carefully crafted questions allow partial credit to be given throughout a question. The question below allows me to check the understanding of direction cosines, projections in a plane, and magnitude along a line where a student needs a position vector and a unit vector.

Figure 6. Sample Exam Question from Moodle



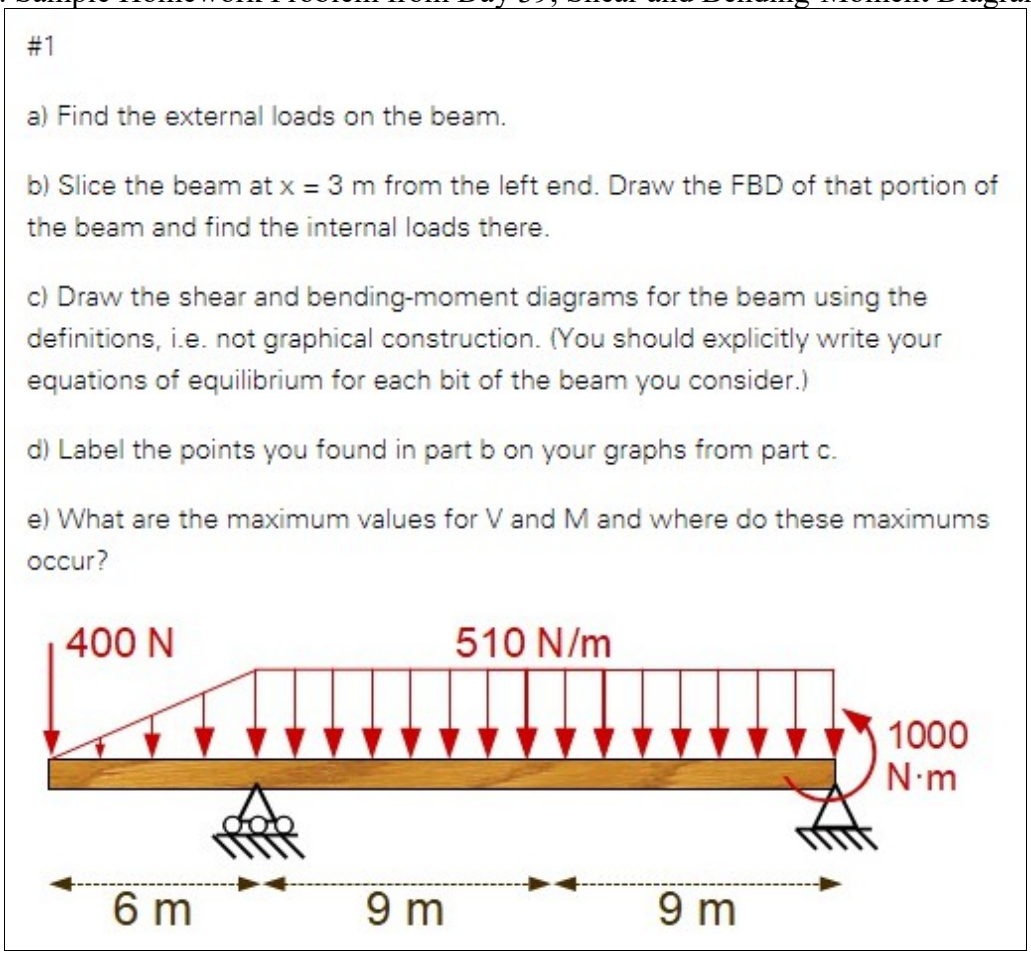
Each semester students take three midterms and a final exam. Each midterm might have 8-10 questions. (The problem above was worth 15 points out of 100 on the Spring 2019 exam.) Over the semester only two problems are hand-graded: a particle FBD and a rigid-body FBD.

Each day students are given a list of specific learning objectives from that class. Sample homework problems and sample exam questions from that day's material are available all semester. On-paper homework is written from scratch every semester, collected every day, and only available the day before it's due. (See sample in Figure 7.) Each day homework is graded by TA's (though we're moving to undergraduate graders in Fall 2019.) On-paper homework amounts to 15% of students' semester grades.

Creating new homework problems does take significant time. However I believe it is essential for students to learn higher-order thinking. The ability to digest what you know and apply it to a new problem is not a switch which can be turned on at will when a student has never experienced a problem where she was supposed to solve the problem on her own, a problem where the solution wasn't as close as a Google search. At some point in the semester I believe students need

to solve unfamiliar, complex problems in an unaided and untimed manner. Solution manuals are immediately available as soon as a textbook is published; online problem banks right now are primarily small edits or changed numbers on problems which also have solutions online. The only way I have found to get unaided, untimed, unfamiliar, and complex problems is to write new problems.

Figure 7. Sample Homework Problem from Day 39, Shear and Bending-Moment Diagrams



Starting in Spring 2019 homework is graded by my team inside Gradescope. That program allows us to streamline the communication with the students. We can see which set of students made particular mistakes. Students get better feedback since a grader can type the same sentence only once and then apply it to all the students who made that mistake. Gradescope has also streamlined regrade requests significantly.

During each spring and fall semester, one of my in-class sections is simulcast to rooms at other universities or colleges. Generally I have two off-campus sections per semester with between 5 and 40 students in each. These students also work in 3-person groups and complete all the same assignments and exams as my Raleigh sections. The flipped classroom has been a great boon for students who are not in the front couple rows of the local lecture: their access to the material is equivalent to those who are in the same city as I am.

Originally online office hours using web conferencing software were used to meet with the distance students. Increasingly the meeting space online is used for all of my students. Online sessions are available for any of my students now. We can share my screen to go over exams or homework.

And last but not least, TurningPoint clickers have been replaced by TopHat for in-class quizzing. Students use their own devices to answer the initial quiz and the participation questions throughout the hour. Students get a daily grade each class day. Each class begins with a 2-3 minute quiz which makes up half of their daily grade (50 points for correct answers, 25 points for incorrect answers, and 0 points for students who are late.) The other half of the daily grade comes from participation during class. The great disadvantage of using TopHat is that students now have their devices out during class. While I routinely will have to ask students to stop texting in my class, it doesn't turn out to happen as often as I had feared.

Students rate their peers once a week using TopHat. The initial quiz allows me to incentivize coming to class prepared.[13] The peer evaluation comes at the end of class and is included in the student's participation grade. The evaluation from their teammates helps students recognize peers who have really helped them understand – and it helps me identify the students who are not working well with others even beyond what I can see as I walk around in the class.

Current Course Content / Extent:

Students are exposed to a full docket of topics in the current course. The course content is thorough.

- 2D and 3D equilibrium (particles and rigid bodies)
- centroids by integration and composite bodies in 2D and 3D
- moments of inertia by integration and by composite bodies
- products of inertia and mass moments of inertia by composite bodies
- fluid statics: pressures up to and including two different fluids on slanted and curved plates by integration and by algebraic methods
- dry friction: slipping vs tipping, application on belts, wedges, rolling surfaces, and screws
- shear and bending-moment diagrams by definition and by graphical construction (at least 15 examples each)

We don't cover axles & bearings, catenary loads, and virtual work.

Because of the flip, I can teach that student who will go on to get a Ph.D. in Aerospace Engineering as well as the student who is struggling to pass. In class twenty-eight I bring a flexible I-beam to class. Students can see and feel that it's easier to bend the I-beam one way rather than the other-way. Then they calculate how much harder it is.

In that same class students who are really excelling have the opportunity to calculate the area moments of inertia I_x and I_y by integration using the same differential element. Students can choose to extend their knowledge or practice what they might almost but not completely understand. (see Figures 8 and Figure 9)

Figure 8. First Sample Problem from Class 28, Simpler.

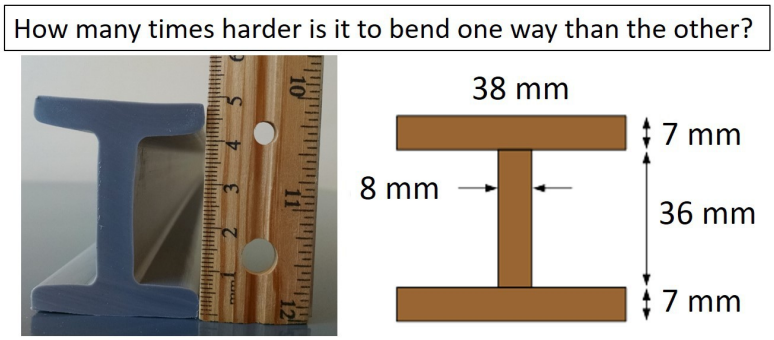
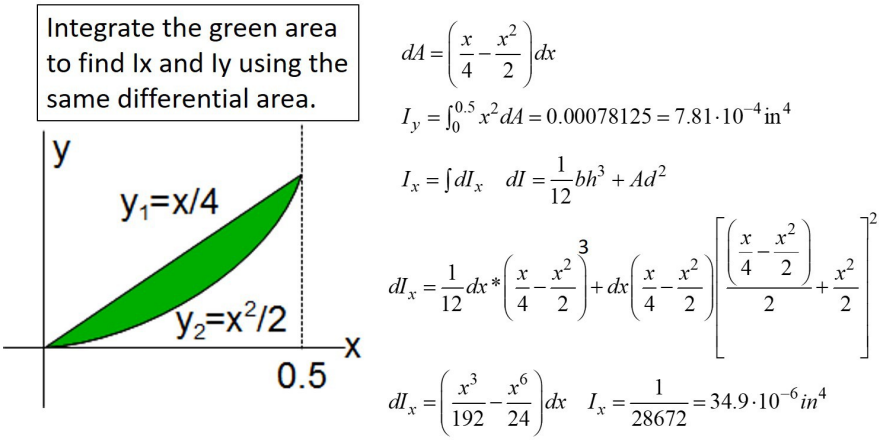


Figure 9. Second Sample Problem from Class 28, Harder.



The ability to tailor the class content to all the levels during each particular class is fantastic. The flipped class allows me to meet each group of students where they are on that day.

Current Drop/Withdraw/Fail (DWF) Rates:

During Fall 2018, after the drop date, I had 300 students enrolled. Of those, four have grades which are on hold for external issues. Fourteen stopped attending class. Only five students took the final and failed (1.7%). 257 students passed but with the C- required to go on in the department (87%). Statics is very difficult or very uninteresting for some students. This setup allows students to identify before the drop deadline that they will probably not succeed for one reason or another.

Spring semesters have DWF rates higher than this: spring tends to be either students who are out of sequence with their program, who are taking Statics out of their major, or who took it before without success. I continue to look for ways to increase their learning.

Student and Peer Evaluations:

My Statics class was evaluated by three of my peers as part of the departmental peer evaluation process in Fall, 2017. The consensus peer review gave the class 4.9 out of 5. The previous peer evaluation in Fall, 2012 was 4.7 out of 5. As I have become more comfortable with the flipped

class, the students and I are better able to come to a great atmosphere in the classroom which is helpful to the student success.

Many students are very uncertain about the flipped class. Students prefer the familiar, and they come in believing that my class is harder than the others they've had because of the flip rather than because of the course material we cover. Most are converted by the time they leave: students were surveyed about whether they'd take an online-only class vs a flipped class if they had to make their selection over again and 91% of my students said that they would take a flipped class again vs online-only.

Student comments tend to be along these lines:

- "I would just like to take a second to thank you for being a tough professor. I had always heard how awful it was to have you as a teacher and I believed it at first, but as the semester went on I realized that you truly cared about the subject you were teaching along with the students in your class. You made me work extremely hard for my B+ and that is practically the first time I have had to work that hard in any class I have ever taken. It made me a better person, engineer, and student after completing your course and I hope that you continue teaching with your passion that you had throughout the entire semester."
- "There's a lot of naysayers about this course, but Howard has clearly figured out how to teach Statics the best way possible. If students do the work, use the material provided to them, and provide the amount of respect that this class deserves they'll do well."
- "Still not a fan of the flipped class since it is drastically different then what I am used to but our professor is great and is helpful. More office hours would be nice on days we don't have class."
- "This course has an extremely heavy work load, something I had never experienced before. That isn't a bad thing though, it taught me how to actually work for a grade and I learned the material. The preparatory videos and notes are crucial to understanding the material with the flipped class environment and they were very valuable in making sure I was prepared for class each day. I definitely learned the material and retained it."

Summary:

Consider these students:

1. Abdul is a highly motivated student who really struggles to understand the material.
2. Beth is highly gifted and comes from a really strong preparation but really struggles with the motivation to do the work.
3. Chaz is a solid student, does the homework most of the time, and mostly understands.
4. Diane really doesn't care at all; it turns out she doesn't do the work and probably won't finish the class.

What can I do for Diane? The best I can do for her is to let her know early that this class isn't for her. She is helped by the daily quizzes which quickly start to make no sense. She sees first hand that other students have come to class prepared. Diane almost always fails the first exam which is at the end of the third week of class. Sometimes Diane figures out that she needs to step up her efforts, but most often that doesn't happen. In my original lecture class Diane might not have

determined that she would fail until half way or three-quarters of the way through the semester. In the flipped class she knows by the fourth week of class.

Beth is gifted. She spends maybe 15 minutes a day prepping for class. Because she's on top of it and well prepared for the info, it makes sense and she doesn't need to spend any more time with the material than that. Beth would be that person in the lecture who ends up browsing on her phone because she's bored.

Abdul doesn't find it quite so easy, but he can watch the video repeatedly. He can also read through the text assisted by the skeleton notes and review the online course notes until the multiple streams of information make some sense. Because it's before class, Abdul also has the opportunity to ask questions of instructors and TA's before class even begins. He also will be in a group with other students during class who might understand different bits of the material than he.

Chaz does about half the prep work. But he's in class with Abdul who has done it and between the both of them, by the end of class both understand. (And Beth helps out when she can be bothered to do so.) Fellow students can often answer the question in a way that a professor cannot: with the eyes of someone who just learned that material recently.

In a traditional lecture class, all four of these students have the same material offered to them. But their needs are very different. We tailor the lecture somewhat to the students we have in class, but it can't reach everyone at the level they're at. The information comes at only one speed. And it's of fixed length: if you spend more time on a single topic, you of necessity leave something out. But in the current redesigned class, the material is available for just-in-time learning tailored to the student's particular needs with me on hand to help with the hard part of applying the material to new problems. I believe it has been a great success.

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