Online-Only Statics Compared to a Flipped Classroom

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Abstract

Engineering Statics at NC State University (NCSU) in the Mechanical and Aerospace Engineering Department (MAE) is taught as a flipped class where lecture materials are online and class time is spent working problems in groups. The flipped format, though effective for most students, is not ideal for every student: a pathway is needed for students where English is a foreign language, where social interactions are difficult or impossible, or where thrice-weekly classes are an obstacle. As an attempt to meet that need, an online-only section was taught (sometimes called distance education) using all the materials from the flipped class to help the population of students who who could not enroll in the flipped class for whatever reason. Students had access to short concept videos, example videos, written notes, and hour-long videos of both the flipped class and old lectures. Online quizzes were required as well as TA-graded homework. Results indicate that student performance did not equal that for the flipped class. Furthermore the differences in results were not explained by differences in the demographics of the the student populations except in the nonresident-alien population. While the online-only format using the flipped materials can be a pathway for some students, online-only Statics does not seem to result in similar student outcomes.

Introduction

Engineering Statics is the first course in engineering for many students. Though Statics is a service course for many departments, more than 90% of our students come from one of Mechanical, Aerospace, Biomedical, Nuclear, Mechatronics, or Biological Engineering. All six of these departments suggest students take MAE 206 Engineering Statics during the first semester of their sophomore year as their first three-credit-hour engineering class.[1]

Statics is a required course for almost every student who takes it. At NCSU in Mechanical and Aerospace Engineering (MAE), Statics is taught by Anna Howard for every section in fall and spring semesters. Though Civil Engineering has a comparable Statics class, the majority of the students discussed here felt forced to be in this class.

Students report finding the course to be more challenging than they expected. A very typical comment:

> "In the past, I have been able to simply work through examples to the point where I can do them in my sleep, and the result would be adequate preparation for the test. This only worked because in my previous classes, all of the problems I faced looked pretty much the same. The test was simply a permutation of the book examples. Now I am noticing that in MAE 206, the situation is completely different. The web page for the day has problems of a certain form, but these will be completely different than the questions you ask during the lectures."

Learning how to focus on the principles of a class and apply them to new situations is an unfamiliar approach to many students. Learning how to learn becomes an unexpected and often unwelcome addition to the students' semester. Many do not persist to graduation.[2]

Much research has gone into how to help students succeed academically despite disparate preparation levels as well as decreasing numbers of hours students will spend on a class. Flipping a class has had success in increasing student retention and improving grades.[3-6] Statics was piloted as a flipped class in individual sections at NCSU between 2010 and 2013. Since 2013 all regular sections have been taught as a flipped class with the exception of the online-only sections discussed in this paper.

Flipped classes clearly work well, but they are not equally accessible to all the students who need Statics. Flipped classes work best with teams of students who can attack a problem together.[7] We know that about 3% of students at NCSU are nonresident aliens, many with English as a second language; language difficulties can can hinder the effectiveness of the group for the flipped class.[8] Returning students who are much older than their peers, parents with young children, and students with disabilities can struggle to succeed in a group of 19-year-olds. More than 55% of our sophomores hold job; 81% of those work off campus.[1] Students with social anxiety can also struggle.[9]

This project sought to determine whether a student who was released from the need to come to class could be just as effective as one who was forced to come to class and work with their peers to solve problems. Online Statics has certainly been effective elsewhere.[10-12] No extraordinary effort was made to engage the students beyond the material online.

Statics is principally a fall course for many majors. Three sections of flipped Statics are available each fall with enrollment limited to 332 students. Online-only statics is only offered during Fall semester. The online-only section has been popular with students for whom English is a second language and for students who are off-campus or non-traditional students. While there are traditional on-campus students enrolled in the online-only instance, the percentage of non-native English speakers and those with families or full-time work commitments has appeared higher in the online-only classes than the flipped classes which are offered on-campus only (with attendance required) three times a week.

Flipped Classroom Description

The flipped class for Statics at NCSU includes multiple learning objects to allow students to attack the materials as best befits their learning styles. These objects are roughly broken into offline, online, and in-class materials.

Offline materials are based around the text: Vector Mechanics for Engineers: Statics by Beer, Johnston, and Mazurkek (9th or 10th editions allowed.)[13-14] Before each Monday-Wednesday-Friday class, students are asked to read the text and complete skeleton notes that are found in the required course pack though completion rates are very low.[15] The course pack also includes supplementary materials on vectors and free-body diagrams.

Online materials are organized by class day. Each day includes an outline of the materials, a to-do list for that day, and a set of html class notes. Though a link is provided to old lecture videos, the content from lectures are instead divided into many short videos. The concept introduction videos average 5-6 minutes with an average of 2 per class period. Students are required to watch

these videos before coming to class in addition to whatever other preparation they do.

In-class time is spent principally working problems with a team of three. Each team has a single whiteboard, one marker, and one eraser. Teaching assistants and the professor roam the class to assist teams or give feedback on work. Each problem is provided ahead of time in the course pack. A video of each in-class problem is also available online in the class notes: each problem was recorded with a LiveScribe pen and has subsequently been moved to YouTube for easy access, about 5-6 minutes in length.[16] PDF copies of the problems are provided for students who wish they had something to review from class. Since spring 2016, simple demonstrations have been used for the flipped class.[17]

Students also had access to several message boards (forums) in which to ask questions.

Online-Only Description

Students were given an option during four successive fall semesters to take the class online-only. Students had access to all the online materials as the flipped section. The only opportunity students in the online-only section did not have was being in class to work with a team on the problems. Students could view videos of these class sessions and were encouraged to work the problems themselves and view the short demonstrations done during class.

Students in the online-only section were encouraged to form study groups to work through the problems from class, but anecdotal evidence suggests that they principally worked on their own. All of the example problems from class were available as video example problems: student comments suggests that they watched videos and read the html notes more often than working the problems themselves.

Students in all sections shared a similar grading format. The three midterm exams (15% each) and the final exam (25% of the semester grade) were identical for all sections. The homework was split between computer-graded homework in Moodle and on-paper homework which was graded by TAs. The computer-graded homework was presented as a series of Moodle quizzes where students had three attempts to get the problems correct with the highest grade counting. The on-paper homework could be scanned and submitted online but it needed to have been done on paper with pen or pencil.

Comparison #1: Did students want to switch sections?

At NCSU most distance education (DE) courses are 600-level courses. Engineering Online at NCSU (EOL) offers Statics to distance sites in Havelock, Wilmington, and Asheville. These presentations are offered in a classroom with a Polycom system so that students are in a classroom at the same time as the instructor and other students in Raleigh.

The classes being discussed here as online-only were not taught under the auspices of the DE or EOL organizations at NC State. The online-only Statics was offered as section 4. Though there was a note placed in the registration system explaining the course, some students didn't read it. As a consequence, the first two times the course was offered as online-only there was a subset of

students who were shocked to find themselves in an online-only class. During fall 2015 and 2016 the online-only section was marked as by-permission-of-instructor. Students were required to affirm that they understood the course was online-only and that they believed they could succeed in that format before they were allowed to register for the class. Enrollment dropped from 40 and 54 in the first two years down to 18 and 28 in the next two years. We had no way to determine whether the drop was due to the fact that the course was online-only or whether the permission of instructor was enough of an impediment to make students not even look again at the course.

In 2013 students were not offered the possibility of moving to a flipped classroom as other students dropped out; as a consequence only 1 out of the 40 students moved from the online-only section to a flipped section. After 2014 students were offered the possibility of switching to a flipped class.

The 2014 section where permission to enroll was not required saw 10 out of the 54 students switch to a flipped section (18.5%). In 2015 and 2016 where students had to attest to understanding the format before they began, the number of students who switched to a flipped section dropped to 2/18 (11.1%) and 5/28 (9.8%). The drop in the number of students switching sections is assumed to be since more of the students chose to be online-only, but this is only a presumption. Students who switched from one section to another are excluded from the remaining data presented here.

In Fall 2014 and 2015, students were asked why they took the section they took as shown in Table 1. Thirty students from the online-only section and 417 students from flipped sections responded to the survey.

Table 1: Student Reasons for Taking Course Format

		Online-only		Flipped	
1.	I had a friend who was already registered in this section.	1	3%	6	1.4%
2.	I knew that the other sections were "flipped" and I thought that individual study would be better for me than working in groups.	1	3%	3	0.7%
3.	I really like online learning.	4	13%	2	0.5%
4.	It was the only one still with open seats. (The selection was really made for me.)	4	13%	64	15%
5.	The time was convenient. (Or, the other class times were inconvenient.)	15	50%	317	76%
6.	other or no response	5	17%	25	6%
	Total:	N=30		N=417	

Choices 2 and 3 above were considered to be students who really wanted to be in the online-only class, but this amounted to only 5 of the 30 students who were registered for that class. We concluded that the majority of the students taking the online-only sections did not purposely choose to study Statics online. For comparison, these same two questions were asked of the students in the flipped class. (Those students who chose choices 2 and 3 above were deemed to

have not understood that there was a different kind of section available.) The vast majority of the students in the flipped section chose that section for convenience.

The same survey instrument was used to ask students, “If you had to choose a section for Statics again, which section do you think would be best for you?” In the online-only class, 15 of 30 students said that they would register for the online-only section again (50%) with the remaining 15 saying they would move into a flipped-style classroom. In the flipped classroom, 378 of 417 (91%) of the students in the flipped section said they'd choose to take a flipped class again rather than moving into an online-only section. That is, by the end of the semester, students who had been in the flipped class even when they took it only for convenience seemed happy to be there. Students in the online-only section were less content with half of the students saying they would have taken the class differently.

The general dissatisfaction with the course showed up in the end-of-semester evaluations as well. The university-administered class evaluations ask students to rate “Overall this course was excellent” on a 5-point Likert scale. Department averages for this are in the range of 3.9-4. All versions of Statics tend to be lower than this. The department has in the past attributed these lower numbers to the high rate of students failing to pass the class and to inexperience with engineering in general. Table 2 shows the comparison of the ratings from the students in the flipped class to those in the online-only class.

Table 2: End-of-semester Class Evaluation

	Flipped Rating	Flipped, N	Online-Only Rating	Online-Only, N	Difference
Fall 2013	3.5	284	3.5	33	0.004
Fall 2014	3.5	279	2.6	45	0.854
Fall 2015	3.7	320	2.6	16	1.078
Fall 2016	3.8	193	3.8	13	0.023
	3.60	1076	3.02	107	0.58

While in some semesters the ratings seem comparable, overall there is a half-point difference between the ratings of the course between the flipped class and the online-only class. (This rating is separate from evaluation of the professor.)

Comparison #2: Did students persist in the class more in one section than another?

Did students complete the course at a substantially different rate in either the flipped or online-only classes? The data on students was expanded from that which the registrar can offer to include students who register and drop before the first day of class or who drop before the first test.

Students are divided into those who never came to class or logged in, who came but did not take the first test, who took the first test but not the final, and who took the final exam. Students who switched from online-only to flipped sections or vice versa are excluded from Table 3 below.

Table 3: Final Disposition of Students

Completion Rates	Never came:		Didn't take first midterm:		Didn't take final:		Took final:		Total
Flipped Course	155	11%	62	4%	79	6%	1123	79%	1419
Online-Only 13-14	18	17%	15	14%	13	12%	63	58%	109
Online-Only 14-15	12	24%	1	2%	3	6%	35	69%	51

The turnover at the beginning of a semester is very large with 11 - 25% of the people not persisting to take the first exam. These students are changing their classes around or trying to decide what major to be in. Whether or not the student is successful in the class cannot be said to have anything to do with the class if the student never attends. Still, the percentage of students who toy with the idea of taking online-only statics and then do not is twice the percentage of those who decide not to take the flipped class.

A serious student is considered to be one who takes the first exam which is given at the end of the third week of classes. An additional 4% of students attend some number of classes but do not take the exam. After the requirement that students in the online-only section receive permission to be there was implemented in 2014, the number of students who started the semester but did not take the first test dropped considerably.

In the flipped sections, 79% of the students who put Statics on their schedule even temporarily go on to take the final exam. Considering only the students who take the first test (1202 students), 93.5% of the students persist to take the final exam.

The open-enrollment online-only sections in 2013 and 2014 had a much lower persistence rate. Only 58% of students who considered online-only Statics took the final. Of the 76 students who took the first exam, 63 of them went on to take the final: 83% compared to 93.5% for the flipped sections. An additional ten percent of students dropped out during the semester in the online-only sections than did so in the flipped sections.

Requiring permission so that the students were forewarned did improve this persistence rate (though the enrollment decreased significantly). The percentage of those who enrolled however briefly in the online-only section and who went on to take the final exam rose to 69% from 58% when permission was required. Of the 38 students who took the first test, fully 35 went on to take the final: this rate 92% is very much in line with the persistence in the flipped section.

Comparison #3: Of the serious students, how did they do?

This section considers only the students in the sections who took the first exam at the end of week three. For example, we're looking at the 1419 total students in the flipped class minus the 155 students who never came and the 62 who came but did not take the first exam = 1202 remaining students in the flipped class. Table 4 shows the final outcome for students who persisted long enough to take the first midterm.

Table 4: Student Success of Those Who Took the First Test:

	Didn't take final				Took Final						Total	Percent Passing
	W	F/U	Drop	D	F/U	D	S	C	B	A		
Flipped Course	36	29	13	1	26	63	3	270	487	274	1202	86%
Online-Only 13-14	3	4	6	0	2	4	0	11	14	4	48	60%
Online-Only 14-15	0	3	0	0	6	8	0	20	21	8	66	74%

* W = withdrew from the class, S & U = successful or unsuccessful (aka pass-fail)

At NCSU earning a C- or better in Statics is required to go onto Dynamics and Solid Mechanics. So one measure of the success of the course format is how many students are able to learn the material well enough to proceed. Clearly as shown in Table 4, the percentage of students who can pass the class is lower in the online-only versions of Statics. Additionally the percentage of A's in the flipped class averages almost 23%. Though these online-only students took exactly the same exams and had the same homeworks as the flipped classes, only 8% in the first two years and 12% of the second two years were able to earn A's.

Comparison #4

In any comparison care must be taken that the groups being compared are actually comparable. We know that persistence can be related to race, for example.[2] We wanted to account for student ability, as well as any differences due to gender or race/ethnicity. Student ability in this case was defined as student performance in Calculus II and Physics for Engineers and Scientists, as well as the number of times each of those courses was taken. While the university has a formal policy of limiting course retakes to two attempts, there are occasional exceptions made, and they are included in these data.

Since our research question involved the investigation of performance in Statics while taking into account a number of control variables, we selected multiple linear regression as our analysis technique. At its most basic level, regression is an attempt to draw a line through a series of related data points in an attempt to demonstrate a relationship between variables.[18] Beyond this however, regression procedures allow for the inclusion of multiple independent variables and an understanding of how collectively these independent variables influence a dependent variable. Researchers can examine the coefficient of an independent variable while mathematically holding constant the other independent variables, which in our case are the four control variables.[19]

We started by collecting the final grades of all students who completed the statics course in the fall of 2013, fall 2014, and fall 2015 from the registrar so we could get data related to performance in Calculus II, Physics for Engineers and Scientists, gender, and race/ethnicity from university databases. In our analysis, we employed a listwise deletion, whereby only cases that had valid values for each variable were included in the analysis. This resulted in a final sample

for analysis that included 505 students, 48 enrolled in the online class and 505 enrolled in the flipped class.

Students were matched to the numerical grades from MAE 206 (0-100). Because the dataset is different from above, the results in Statics are shown in Table 5.

Table 5: Statics Performance for Students with Available Demographic Data from Registrar

	Statics Grades, Flipped		Statics Grades, Online-Only		Statics Grades, Total Sample	
Term	Mean	SD	Mean	SD	Mean	SD
Fall 2013	79.65	11.13	75.46	11.78	79.23	11.23
Fall 2014	77.95	10.60	67.15	20.78	6.72	12.59
Fall 2015	76.03	12.1	70.11	18.41	5.74	12.49
Overall	77.74	11.42	70.71	17.59	77.13	12.22

The demographic data for this group of students is shown in Table 6 for gender and Table 7 for race.

Table 6: Sample Demographics by Gender

	Statics Participants, Flipped		Statics Participants, Online-Only		Statics Participants, Total Sample	
Gender	N	%	N	%	N	%
Men	420	83.2%	44	91.7%	464	83.9%
Women	85	16.8%	4	8.3%	89	16.1%

Table 7: Sample Demographics by Race

	Statics Participants, Flipped		Statics Participants, Online-Only		Statics Participants, Total Sample	
	N	%	N	%	N	%
Caucasian	393	77.8%	27	56.3%	420	75.9%
Nonresident Alien	34	6.7%	7	14.6%	41	7.4%
Hispanic	21	4.2%	5	10.4%	26	4.7%
Two or More	21	4.2%	3	6.3%	24	4.3%
Asian American	18	3.6%	2	4.2%	20	3.6%
African American	11	2.2%	1	2.1%	12	2.2%
Unknown	6	1.2%	2	4.2%	8	1.5%
American Indian	1	0.2%	1	2.1%	2	0.4%

As a whole men made up 83.9% of the students; Caucasians almost that many at 75.9%. As an aside it is clear that efforts need to continue to be made to encourage enrollment of underrepresented minorities in our department.[2]

The students' highest final grade in Calculus II and Physics for Engineers and Scientists served as two of the control variables. To limit the number of dummy variables used in the model, we converted their final letter grade into the numeric equivalent that is used in calculating grade points (i.e. A+ = 4.33, A = 4.00, etc).

The final control variables for this study were gender and race/ethnicity. We chose not to use incoming GPA because the presence of many transfer students would have deleted too many students from the sample. Consistent with appropriate treatment of categorical data in multiple regression analysis, dummy variables were constructed for these variables.[18-19] Men and Caucasian students served as the reference group. Lastly, we variable to represent which class a student enrolled, online or flipped. This variable too was treated as a dummy variable with the flipped classroom serving as the reference group. The baseline comparison of the student set from the registrar is given in Table 8.

Table 8: Comparison of Students in Flipped and Online-Only

	Calculus II, Flipped				Calculus II, Online-Only				Calculus, Total			
	GPA		Attempts		GPA		Attempts		GPA		Attempts	
Term	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fall 2013	3.48	0.43	1.04	0.23	3.28	0.64	1.06	0.24	3.46	0.72	1.04	0.22
Fall 2014	3.36	0.75	1.04	0.20	3.22	0.72	1.05	0.22	3.34	0.75	1.05	0.20
Fall 2015	3.37	0.72	1.03	0.18	3.10	0.75	1.04	0.21	3.36	0.72	1.04	0.20
Overall	3.40	0.73	1.04	0.21	3.21	0.68	1.08	0.28	3.38	0.73	1.04	0.21
	Physics, Flipped				Physics, Online				Physics, Total			
	GPA		Attempts		GPA		Attempts		GPA		Attempts	
Term	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fall 2013	2.89	0.76	1.05	0.21	2.94	0.70	1.06	0.24	3.48	0.73	1.04	0.23
Fall 2014	3.06	0.67	1.06	0.23	3.05	0.76	1.05	0.23	3.34	0.75	1.04	0.20
Fall 2015	2.95	0.76	1.10	0.32	2.90	0.63	1.10	0.32	3.36	0.72	1.04	0.20
Overall	2.97	0.74	1.07	0.26	2.98	0.70	1.06	0.24	3.38	0.73	1.04	0.21

Results of the first regression analysis that examined the non-stratified sample found that the overall model was statistically significant, $F(13, 539) = 22.98$, $p \leq .001$. When examining the coefficient of determination, 35.7% of the variance in final statics grade was accounted for by the model.

The demographics data did not show a large difference between the students who took the online-only version versus the flipped version.

When controlling for all the variables in the model, a statistically significant amount of variability was observed in Statics final grade based on course format. Students who completed the online course on average performed at more than half a letter grade lower than students who completed the flipped class. Table 9 presents full results from the regression analysis.

Table 9: Summary of Regression Analysis

Variable	B	SE B	β
Physics Grade**	5.63	0.67	0.34
Calculus II Grade**	3.84	0.67	0.23
Physics Attempts**	-8.03	1.68	-0.17
Calculus II Attempts*	-6.33	2.15	-0.11
Online-only vs. Flipped**	-5.90	1.53	-0.14
Nonresident Alien vs. Caucasian*	-4.64	1.66	-0.10
African American vs. Caucasian	-4.74	2.96	-0.06
Two or more Races vs. Caucasian	-1.64	2.09	-0.03
Gender Female vs Male	-0.92	1.19	-0.03
American Indian vs. Caucasian	4.05	7.15	0.02
Asian American vs. Caucasian	4.05	7.15	0.02
Unknown Race vs. Caucasian	0.31	3.81	0.00
Hispanic vs. Caucasian	-0.07	2.05	-0.00

*$p \leq .01$
** $p \leq .001$

The statistically significant independent variables were course format (online-only vs flipped), Calculus II and Physics grades, and the number of attempts at Physics at $p \leq .001$. Additionally the number of Calculus II attempts and nonresident alien status were significant at $p \leq .01$.

Discussion

Online-only statics serves the needs of a small minority of my students. When such a class was offered and when permission was required (so that I knew that students understood what they were getting into), about 7% of the students chose to take the class online-only. Persistence between the first midterm and the final did not noticeably change between the formats.

The correlation between performance in prerequisite courses and performance in Statics is not surprising. The percentage of students in the online-only section who were nonresident aliens

was more than twice the percentage in the flipped section (14.6% vs 6.7%) which suggests that our hypothesis may have been correct that students with language difficulties may have preferentially enrolled in the online-only course.

The difference in student grades for the different formats across the entire sample was disheartening. The students in the online-only section performed statistically significantly worse than their peers in the flipped sections. Initially our hypothesis was that a different demographic of students would enroll in the online-only class; we expected that controlling for variables such as Calculus and Physics grades would yield a more comparable experience for the students in either format. That hypothesis did not hold up. The statistics suggest that the format is itself to blame for the five-point difference in the student grades. Part of this difference may be explained by the success in the flipped format. If a pure lecture format were available to compare to, the grades in the online-only section might be very comparable.

There are multiple schools of thought on whether students should be forced into classes that have a greater chance of success or allowed to under-perform in formats which are more desirable to the individual student. Indeed one of the students in the online-only section had tried to come to campus to take classes but failed when family and professional demands kept him from being able to attend. For him the online-only class was a blessing which provided the only pathway for his success.

As a pathway, this incarnation of online-only statics did allow students to take the class who might not otherwise have been able to. To that extent online-only Statics was definitely a success. During spring 2017, another student was allowed to follow this pathway as an independent study alongside the flipped classroom due to health limitations which made attendance problematic. Such an approach might balance the desire to serve students who cannot take the flipped class without leading students astray with an implicit promise that the online-only is just as good.

Future Work

We strive to teach the students we have rather than the students we wish we had. We have tried pure lecture, blended learning, flipped, and online-only instances as have others before us.[20] The father with the newborn baby and the student from China found the online-only section to be a better fit for their lives than the flipped class but it is statistically likely that their grades suffered from that decision. We must determine whether to allow students to choose a pathway when we believe that their grades will be lower by half a letter grade to a full letter grade. And we will need to determine what information we can provide to help students who are not in such extreme circumstances make the best decision for themselves.

We need more robust data to do that. We hope to expand our multiple linear regression model to include items such as the Test of English as a Foreign Language scores which could help us tease out whether language proficiency or culture clash plays a bigger part in student success in Statics.

The flipped presentation of Statics at NC State University remains the most dependable

presentation technique for student success, but it remains true that some students cannot participate or will not participate in a flipped class. For those students, another class style needs to be developed which approximates the success of students in the flipped sections. Alternate formats which mandate and reward group performance may work. The balance between face-time and independent study will vary between groups of students.

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