Online-Only Statics Compared to Flipped Class

A.K.T. Howard and M.T. Stimpson
North Carolina State University, Raleigh, NC, United States

***Abstract*—Enrollment pressures in engineering can encourage departments to offer online or distance versions of critical path classes. Materials developed for a flipped classroom offer a tempting path to the online-only environment. We compared the performance of students in the flipped sections vs the online-only sections using identical graded assignments and statistical profiling to determine whether the online-only class was equivalent in student learning outcomes. Message boards and office hours were available for all students. Students performed statistically significantly worse in the online-only class with grades that were approximately 6 points lower than those in the flipped class. Flipping the class is known to have an increase in student grades over lecture of about the same amount. We conclude that the flipped classroom is better than the online-only version of Statics with the caveat that online-only Statics does offer a pathway to students who would not otherwise be able to take the class at all.**

***Index Terms*—distance education, flipped class, Statics**

I. INTRODUCTION

A. Pressures on Higher Education

The cost of undergraduate education is steadily increasing while the support of undergraduate educational institutions by the state is declining. In constant dollars tuition has more than doubled over the last 40 years; forty-five states are providing less per-student funding than they did in 2008 [1,2]. For the first time in 2017, half of the cost of higher education is being born by tuition rather than appropriations for public colleges and universities [3]. Enrollment which increased significantly during the recession has decreased but not to pre-recession levels [4]. Engineering degrees awarded by the 352 reporting schools increased by 32,000 students between 2009 and 2015; full-time student enrollment increased by almost 183,000 students [5,6].

Coincident with the increase in the pure number of engineering students has been the rise in the use of flipped and hybrid classrooms [7]. Uncounted researchers have concluded that students learn well in active, non-traditional classroom settings [8]. Flipped classes most commonly use videos, online materials, or directed readings to replace the traditional lecture for content delivery. At their best, flipped classes encourage students to be active participants in constructing their own knowledge.

Once the materials needed to teach a flipped class are in place, the pressures of increased enrollment on university departments can make online-only education look enticing. Indeed massive open online courses (MOOCs) are one manifestation of exactly this concept: rather than having teachers in each room watching people work problems, let's allow students to work by themselves through the online material [9, 10]. Unfortunately experience has shown how few people survive all the way through a MOOC [11, 12]. Online-only classes serve as a reasonable middle ground between coming to class every day and a full MOOC.

B. North Carolina State University Experience

Two different sources of pressure brought us to teach Statics in an online-only environment in 2012.

First, students seemed to want it. Students were surveyed to see why they had enrolled in the online-only class. Fifty percent of the students said they took the online-only course because it was convenient. Thirteen percent chose it because they really liked online learning. Some students chose the online-only class when their English skills were insufficient to the flipped classroom environment or when home pressures demanded considerable flexibility.

Second, enrollment pressures were mounting. As mechanical engineering became one of the most popular kinds of engineering at NC State, more and more students wanted to take Statics only in the fall. Thirteen percent of the students took the online-only class because it was the only section with seats remaining. For them the online-only class offered a path to graduation that would have otherwise been closed to them.

Administrators can also be subject to misunderstanding the value of the in-class portion of a flipped class: if the lecture is online, they don't see the reason to have space set aside for classrooms, instructors paid to be in those classrooms, and often teaching assistants to help with large-enrollment classes. An online-only version seemed to be a much cheaper way to silence the complaints of students who could not get into their needed classes.

We did not have good data to prove that the in-class portion was critical or even if it was important at all. Certainly active learning has been shown to improve student learning. Also an online-only class had the possibility of students slacking off until something was due. But we did not have data to assess how important the in-class portion of the class was to student grades.

The online-only class was taught five times over five successive fall semesters. Enrollment was higher in the first two years than in successive years. In the final three years the online-only class was open only by permission of the instructor, which cut down on two things: the students who didn't understand what they were getting into and the students who weren't willing to ask for permission.

During the first year when we had no data yet, students were not encouraged to switch formats if they were in a class that was not working for them. In subsequent semesters students who were struggling with the online-only class were encouraged to switch back to a flipped class. Few students ended up switching sections, but the

few that did switch have been excluded from our analysis.

Previous authors have compared online-only classrooms to lecture. Results have shown that students can certainly learn in an online environment.

In this paper we were interested in comparing the student performance in the well-established, flipped classroom for Statics to the online-only version.

II. THEORETICAL FRAMEWORK

A. Constructive Alignment

Biggs' [13] view of constructive alignment serves as our theoretical basis. Constructive alignment is the result of the fusion of two separate strains of thought related to teaching and learning, specifically in this case constructivism and instructional design.

Constructivism focuses on a student's activities related to learning. Through active learning individuals make meaning of knowledge and information [14,15]. Constructivist alignment suggests that instructors should focus on creating active learning environments where students are tasked with synthesizing a personal understanding of acquired knowledge. Assessments are used to take stock of student's understanding and ability to apply that understanding to new problems.

Biggs and Collis [16] detailed a hierarchical structure to student performance, rising from the point where students are unable to understand a concept or perform a task to where students are able to apply and extract previously learned knowledge to new problems and issues. Pickard [17] compared these to the Bloom's Taxonomy which is similarly layered in explaining student understanding [18].

In both Biggs' extended abstract and Bloom's application and synthesis levels, the teacher's challenge is to educate students to the level where students can apply their knowledge to new and complicated problems. As the technology has matured to its present state, more and more classes are being converted to a flipped classroom where students practice the application of their knowledge in a controlled environment [19, 20].

B. Flipped Classroom

Mechanical Engineering Statics was taught as a flipped class for the first time in the spring semester of 2010. The initial design for the class was based on the Scale-Up design by Beichner and his colleagues [21]. Students were assigned readings before class, during class they worked in teams to solve problems. The class has developed over the years to include many different elements: students are asked to prepare for class, apply what they have learned to new problems during class with their teammates, review what they have learned, and then practice on their own with more new problems.

- Preparation:
  - 75 short concept videos posted on YouTube (lecture replacement) [22]
  - Textbook: Beer, Johnston, & Mazurek, Engineering Statics [23]
  - Course pack with skeleton notes for readings and each day's problem statements [24]
- In Class:
  - Groups of 3 students with one white board between them
  - Problems in course pack worked in class while TAs and the professor roam, helping as needed
  - Clickers used to gauge student understanding and preparation
- Review and Practice:
  - Video and PDF solutions of the in-class problems are available [25] embedded in html notes which amount to a second textbook.
  - Old 50-minute lectures, slides from class, slides from the publisher, and extra examples with and without solutions are available for more help.
  - Computer-graded quizzes in Moodle allow students to practice basic concepts. Quizzes can be taken three times with the highest grade counting.
  - New homework problems are written every semester so students face unfamiliar, complex problems by themselves in an untimed environment. These are collected and graded by the TAs.
  - Message boards were available at all times for students to get help from the instructor, TAs, and other students. Office hours were held with online meetings available.

C. Online-Only Classroom

Once all the materials described above were in place, moving to an online-environment required nothing other than telling students they did not have to come to class. Each cohort of online-only students met with the instructor at the beginning of the semester to understand the layout of the course and to meet each other. Study groups were encouraged but not mandated.

Students in the online-only environment had access to all the materials that students in the flipped section did, including the message boards and office hours. The exams and homework from the students were identical to those in the flipped section.

Ten percent of the final grade for students in the flipped section came from clicker questions and class participation. This ten percent was replaced for students in the online-only classroom by 5-question multiple-choice quizzes that directly related to the content for that class day: unlike the computer-graded homework mentioned above, these quizzes were conceptual. These concept quizzes were set up to encourage students to keep up with the work and to see if they understood the main concepts of the day.

Student grades in the online-only section for the concept quizzes were not as high as the in-class participation grades: daily grades averaged 81.9 (σ = 12.5) where concept quiz grades averaged 73.0 (σ = 17.3). To limit the effect of this difference, these grades were excluded from the analysis below. Grading consistency beyond this was ensured by having the same person grade everything graded by hand; most of the grading was computerized and identical for all students.

III. METHODS

A. Sample

We compared student performance data from four semesters (fall 2013, 2014, 2015, and 2016) to answer the question: did the in-class portion of the flipped class matter to student grades and if so how much? The model we tested compared students in the flipped section to those in the online-only section and accounted for the student's gender; race/ethnicity; overall cumulative GPA; number of attempts at taking Calculus I, Calculus II, Physics I, and Physics II; and grades in each of the proceeding classes.

Beginning in 2014, students were given the option of moving from the online-only class to the flipped sections as seats became available. These students have been excluded from our analysis. Our sample without these students included 1,529 students.

We also excluded students for whom we could not obtain data on their gender, race/ethnicity, GPA, or Calculus & Physics grades. Students' grades for Calculus and Physics were straightforward for those students who completed the classes at NC State. For students who passed AP examinations and did not take Calculus and/or Physics at NC State, we matched their AP scores to approximate grades. Students who received transfer credit were removed from the sample due to our inability to acquire grades for these courses. Finally, we also removed any student's second attempt at Statics, choosing to focus only on a first attempt at completing Statics.

Our initial intention was to construct a model that also reflected precollege characteristics such as high school GPA and SAT/ACT scores. But this information was difficult or impossible to obtain for too many students. Rather than reduce our sample size even more, the model only included the items above.

After removing cases due to missing data, we were left with a sample of 708 as shown in Table 1.

TABLE I.
ORIGINAL AND FINAL SAMPLE SIZE BY SECTION

Section	Original Sample (N)	Final Sample (N)
Flipped	1374	647
Online	155	61

B. Procedures

We used multiple linear regression (ordinary least squares regression) to determine whether there were statistical differences in student performance between the flipped classroom and the online-only class. Regression is an attempt to fit a straight line through a series of data points. Regression analysis can be used either to predict a particular outcome/variable or to explain variation in an outcome/dependent variable based on a set of independent variables [26]. We are using regression for purposes of explanation. First, we want to know if the model we test explains a significant amount of variability in student performance in Statics. And if so, then we'd like to know if and to what degree do students in the flipped section of Statics perform better than students in the online section.

Gender, race/ethnicity, and section enrolled were converted to dummy variables. The reference category was male, Caucasian, and enrolled in the flipped section. The use of dummy variables allows for the inclusion of these categorical variables by creating a series of dichotomous variables coded as a '1' or '0', thereby defining group membership [27].

Calculus and Physics grades were converted to numerical equivalents (A+ = 4.33, A = 4.00, A- = 3.67, etc). Credits awarded from AP exams were mapped to grades using the concordance tables found at: https://www.engr.ncsu.edu/academics/undergrad/coda/#ess [28]. Cumulative GPA in the semester the student completed Statics rounded out the independent variables. The dependent variable was the final course average from Statics (0 – 100).

IV. RESULTS

A. Descriptive results

Tables 2, 3, and 4 provide a summary of the dataset analyzed. As mentioned previously, a total of 708 students were included in the final analysis. The vast majority of students in both classes were men (see table 2).

TABLE II.
ENROLLMENT BY GENDER AND SECTION

Section	Women (%)	Men (%)	Total
Flipped	103 (15.9%)	544 (84.1%)	647
Online	9 (14.8%)	52 (85.2%)	61

Similarly, the vast majority of participants were also Caucasian, see table 3.

TABLE III.
ENROLLMENT BY RACE/ETHNCITY AND SECTION

Race/Ethnicity	Flipped (%)	Online (%)
Asian	34 (5.3%)	3 (4.9%)
African American	12 (1.9%)	1 (1.6%)
American Indian/Alaskan Native	1 (0.2%)	1 (1.6%)
Caucasian	502 (77.6%)	38 (62.3%)
Hispanic	31 (4.8%)	5 (8.2%)
Nonresident Alien	34 (5.3%)	9 (14.8%)
Two or more	24 (3.7%)	3 (4.9%)
Unknown	9 (1.4%)	1 (1.6%)

Meanwhile, table IV provides the descriptive statistics for the continuous variables.

TABLE IV.
SUMMARY OF CONTINUOUS VARIABLES BY SECTION

Variable	Flipped (Mean/SD)	Online (Mean/SD)
Cumulative GPA	3.45 (0.41%)	3.22 (0.45)
MA 141 Attempts	0.48 (0.51)	0.53 (0.57)
MA 141 Grade	3.68 (0.56)	3.56 (0.58)

MA 241 Attempts	0.79 (0.47)	0.85 (0.51)
MA 241 Grade	3.53 (0.66)	3.32 (0.70)
PY 205 Attempts	1.02 (0.30)	1.02 (0.29)
PY 205 Grade	3.05 (0.70)	2.97 (0.67)
PY 208 Attempts	1.06 (0.27)	1.08 (0.28)
PY 208 Grade	2.79 (0.83)	2.54 (0.84)
Final Statics Average	71.04 (10.46)	65.16 (14.46)

Results from the regression analysis are listed in table V. The overall model was statistically significant F (18/682) = 34.49, p <= .001. The amount of variance explained by the model was 47.7%. In addition, students in the flipped class were likely to perform 2.38 (t = 2.13, p = .03) percentage points better in Statics than students in the online section. The correlation between the flipped class and Statics performance when controlling for the other variables in the study was considered small, though significant (r = ..081).

TABLE V.
REGRESSION RESULTS

Variable	*B*	β
Female	-1.21	-0.04
Vs Male	-	-
Asian	-1.96	-0.04
African American***	-9.98	-0.12
American Indian/Alaskan Native	0.41	-0.00
Hispanic	-1.73	-0.04
Nonresident Alien**	-3.76	-0.08
Two or More	0.25	-0.00
Unknown	0.56	-0.00
Vs. Caucasian	-	-
Cumulative GPA***	8.01	-0.30
MA 141 Attempts*	-1.64	-0.08
MA 141 Grade	-0.74	-0.03
MA 241 Attempts*	-1.56	-0.07
MA 241 Grade	0.90	-0.05
PY 205 Attempts*	-2.51	-0.07
PY 205 Grade	0.90	-0.06
PY 208 Attempts***	-3.75	-0.10
PY 208 Grade***	3.67	0.28
Flipped*	2.39	0.06
Vs. Online	-	-

*p <= .05
**p <=.01
***p <=.001

V. LIMITATIONS

The biggest limitation we faced was the small number of students in the online-only classroom and the large reduction in sample size due to missing data. We ended with fewer than half the original sample size mostly because of missing data related to what we could gather about the students. We recognize that this is a significant reduction in the sample. The quality of our small sample is preserved by only using students for whom our data set is complete.

Comparing students is always difficult. A model like ours can account for some traits which we believe make a difference in student performance. The data available to us did not however include things like the students SAT scores or high school GPA. We believe that the grades in the prior pre-requisite courses provide a sufficient proxy to separate the student abilities and study habits.

VI. DISCUSSION

We wanted to know if the in-class portion of a flipped class mattered to student performance. Our regression analysis showed that the in-class portion raised a typical student's grade by 3.16 points with p = .008. Even though the in-class portion of a flipped class does not add any material to the course, the value of that team practice when instructors are available amounts to one-third of a letter grade.

Students were surveyed at the end of the semester to see if they would choose the same format again if they could redo their Statics class. The online-only sections had N=30 responses to the survey; 50% of the online-only class said they would take an online-only class again. (Ninety-one percent of the students in the flipped class said they would take a flipped class again with N=417.) For the fifteen students who chose the online-only class and who would choose it again, the 3.16 point reduction in their overall grade did not seem to make the difference in what they would choose: the online-only section serves well a small but non-zero percentage of students.

The differences between the online-only section and the flipped section show that the in-class portion of a flipped classroom confers real value on the success of the students. Online-only classes should not be used as a panacea to fix enrollment issues from an administrative point of view. However, as a pathway to success for individual students, the online-only section is a very reasonable way to accommodate small overflows of students, especially if they can be moved into the flipped sections as seats become available.

VII. FUTURE WORK

The online-only section did see a reduction in student performance. Though the online-only students had extra quizzes to help them keep up, in the future more effort needs to be put into communicating with the students in the online-only section. It is unclear whether students in the online-only section should be separated more from the flipped section which would perhaps build community. Another possibility would be to require and grade message board posts instead of using quizzes to gauge whether students were keeping up with the material. While this would require more manpower, it might also spur students who are struggling to get more help.

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AUTHORS

A.K.T. Howard is a Teaching Associate Professor in Mechanical and Aerospace Engineering at North Carolina State in Raleigh, NC. She is the course coordinator for Statics and has led the redesign effort. She teaches all of the sections in Fall and Spring seeing more than 550 students every year. (email:anna_howard@ncsu.edu)

M.T. Stimpson is Director of Assessment in the College of Engineering at NC State University.