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How Classroom Flipping Affects Coast Guard License Students in Engineering

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With extensive course and curriculum design experience, including Maritime College courses Signals and Systems, Machine Learning, and Programming for Engineers, Dr. Kump is continuously committed to developing an electrical engineering program that best prepares students for the ever-changing demands of industry leaders. Dr. Kump's teaching interests include alternative methods of content delivery, for example, with online education and classroom flipping. He has been recognized by Open SUNY for excellence in online teaching, serves on The Online Learning Subcommittee, and has pioneered The School of Engineering's online course offerings.

HOW CLASSROOM FLIPPING AFFECTS COAST GUARD LICENSE STUDENTS IN ENGINEERING

0: Abstract

Flipped classroom is an active-learning strategy in which student activities that are traditionally completed at home are exchanged, or "flipped", with activities traditionally completed in class. In engineering, this approach usually means class time is used for student-led problem solving and interpreting results—a situation that promotes higher levels of cognitive work in the classroom under the tutelage of the instructor and peers. The flipped classroom model was recently instituted at State University of New York (SUNY) Maritime College in a junior-level engineering course with a student population of largely varying abilities and career goals, including students who seek U.S. Coast Guard licensure. The motivation for adopting the flipped classroom model was threefold: (1) The traditional classroom may be a disconnect for license students who often work in teams and spend many hours in active-learning environments like ship simulators and on a training ship. Thus, it is reasonable to suspect that the flipped classroom model may resonate well with license students who seem to thrive in these hands-on environments. (2) Prior research demonstrates the flipped classroom model benefits a wide variety of students with wide-ranging abilities, which aligns well with the course's student body. (3) Prior to flipping, the course was showing a concerning trending decline in student performance and a wide gap between student and instructor expectations, motivating the instructor to consider alternative teaching strategies.

The objective of this paper is to estimate the effect classroom flipping has on engineering students, particularly license students, and determine the statistical significance of the observed effect. This objective is met by first retrieving the final student grades in the selected course in a timeframe that includes a pre- and post-flipping period (2016-2019), as well as the final student grades in a similar control course that was not flipped during the same time period. The data also include whether or not each student was a license student, which allows for the construction of three datasets: one of only license students, one of only non-license students ("interns"), and one of all students. Then the well-established difference-in-differences (DiD) technique is employed to each of the datasets in order to measure the effect flipping the selected course has on final course grades. Lastly, random inference is applied to calculate p-values and determine the statistical significance of the observed effect. It is found that license students see an average increase of +0.583 grade point average (on a 4-point scale), at a confidence level of 99%, which is a greater effect than what intern students see, which is a +0.474 increase on average, at a confidence level of 95%. Also included are comments and results of a poll that was completed by students in the flipped classroom meant to gauge their satisfaction in the course and what they believe the effect the flipped classroom had on them in meeting the course learning objectives.

1: Introduction

Classroom flipping is a decades-old active-learning strategy that is a popular alternative to the traditional and passive "chalk-and-talk" lecturing found so frequently in higher education. Widely used in humanities courses, the flipped classroom format has recently gained popularity in Science, Technology, Engineering, and Mathematics (STEM) classrooms, but with varying degrees of success

[1]. Prior research has demonstrated that a wide range of students with varying abilities and skill levels can benefit from the flipped classroom format, but the benefits are not uniformly distributed among the general STEM student population. For example, studies [2, 3] have suggested that medical students respond most favorably—reporting heightened enjoyment, decreased boredom and a large gain in knowledge and skills—because the students naturally enjoy collaborative and project-based learning in hands-on environments. In maritime engineering, these same qualities are shared by students who seek U.S. Coast Guard Licensure ("license students"), qualities which are crucial for work in laboratory, welding, ship simulators, and ship operation and maintenance, environments commonly found in license students' curricula. It is interesting to consider, then, if—and by what degree—license students are affected by the flipped classroom format, especially as compared with their non-license engineering student counterparts ("interns").

This paper aims to quantify the effects that the flipped classroom format has on license students. The paper achieves this by performing a difference-in-differences (DiD) [4] analysis on the students' final course letter grades in a recently flipped course in signals and systems, specifically ENGR 383 Signals and Systems—a junior-level electrical engineering course taken by license and intern students at State University of New York (SUNY) Maritime College. A separate analysis was conducted on a license student dataset and an intern student dataset, and it was found that license students' final course grades see a larger boost on average than do interns'. More than final course grades, of additional importance is the student perspective and attitude towards the flipped format and whether or not students perceive that the flipped format helped them meet course learning objectives and Accreditation Board for Engineering and Technology (ABET) learning outcomes [5], especially since research has shown that student perspective can affect their own learning [6]. To that end, this paper also reports and discusses the results of a course survey repeatedly completed by students throughout the duration of the course that was meant to gauge student perspective as the course progressed. The quantitative effects measured from the DiD analysis are supported and explained by these qualitative survey results, forming a single coherent picture of the how license students are affected.

The next section provides the details regarding course delivery necessary to understand the results and discussions that follow. The rest of the paper is as follows: Section 3 explains how specifically the DiD analysis was conducted and how survey questions were written and administered. Section 4 provides the results from the analysis, and Section 5 is an interpretation of those results. The conclusions, limitations, and directions for future work comprise Section 6. References are provided in Section 7.

2: Description of class, teaching methods, instructor

Maritime College's ENGR 383 Signals and Systems is a three-credit, theory-heavy course required of all electrical engineering students (EEs), usually taken in the fifth semester. The class meets twice per week for 75 minutes each meeting. Typically about 30 of the 32 students enrolled in the course each year are EEs; the others are students looking for elective credit in different programs, e.g., marine engineering. Drawing heavily on its prerequisites differential equations and circuit analysis, the course is one of the first courses EEs take for which they are expected to apply mathematical concepts and principles. The required mathematics, however, are not limited to the prerequisite differential equations; instead, the course draws upon the entire four-semester mathematical sequence that culminates with differential equations, which adds to the challenge of the course. Prior to flipping in 2019, the course was showing a concerning trending decline in student course grades and the rates at which they were meeting or exceeding course learning objectives and ABET learning outcomes. The course's instructor believed such a decline was mainly due to an increased laziness or unwillingness of the students to give the homework its due diligence, which is of paramount importance for such a mathematically heavy course. This was the main motivating factor for moving to a flipped format, because such a format can require the students solve homework in class with the instructor present and thus eliminate the possibility of them copying from peers, the internet, or solution manuals; or ignoring the homework altogether.

The course addresses ABET Criterion (1): An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. And separate from ABET learning objectives, the in-house (course) learning objectives are as follows: The student, upon successful completion of ENGR 383 Signals and Systems,

- Will have an in-depth knowledge of the basic principles governing the subject of signals and systems.
- Will have mastered basic Fourier analysis and understand how it applies to engineering.
- Will have improved math skills dealing with logical reasoning, proofs, handling of finite and infinite sums, integration and differentiation, and especially the manipulation of complex numbers.

The ENGR 383 Signals and Systems flipped classroom was designed to have the four elements generally agreed upon in the community as being integral to any flipped classroom [7]. Namely, the course

(i) <u>Allowed students to gain first exposure to new material outside of class.</u> In ENGR 383, students were required to watch a series of sequenced, instructor-made videos and read selected textbook passages prior to coming to each class, excepting exam days. All of this was communicated and made available in the course's learning management system Blackboard.

(ii) <u>Incentivized students to prepare for each class and complete the assignments in (i).</u> In ENGR 383, students were required to complete a single short quiz on Blackboard prior to each class, excepting exam days. Automatically graded by Blackboard, each quiz was five multiple-choice, multiple-answer, and/or short-answer questions only assessing the most recently assigned material, and only the basic ideas. Importantly, students had unlimited attempts to solve the quizzes since students had not yet had the opportunity to discuss the new material with the instructor.

(iii) <u>Provided a way to assess student understanding.</u> In ENGR 383, the Blackboard quizzes in (ii) were due the night before each class meeting, as opposed to right before class. This provided the instructor the time in the morning to review student performance and evaluate which ideas were difficult for students to understand.

(iv) <u>Required students complete activities during class time that focused on higher-level cognitive learning.</u> In ENGR 383, each student was provided the same daily problem set, and students worked together in groups at the chalkboard to complete the problems. Students were told that how they functioned in their group would influence their participation grade for that day. Stronger students were expected to help weaker students, and weaker students were expected to speak up and ask for help as necessary. The instructor would move from group to group, singling out students to ask them questions, have them explain their solutions, or produce the notes they should have taken on the assigned videos and textbook passages the day before.

How they responded to these requests influenced their participation grade. The instructor made sure to address the key ideas with which students struggled, based on the assessment in (iii).

Occurring about every three weeks, students additionally completed five exams throughout the semester, including one at the course's conclusion. On exam days, the first 50 minutes of the 75-minute period were devoted to completing the exam. The remaining 25 minutes of exam periods were reserved for students to reflect and complete a survey about the flipped course format. The survey responses were anonymous and collected in an envelope handled by the students.

Prior to flipping the course in 2019, ENGR 383 was taught in the traditional lecture-based format for which students were expected (but not required) to come to class and take notes. In this format, students were graded on weekly homework assignments and a single group project, as well as three high-stakes exams, the last of which was a long comprehensive final exam. Student participation, which was not graded, was limited to responding to the instructor's timely questions, sometimes volunteering with a raised hand, other times involuntarily being called on. The course content was the same as in the flipped course.

The course's instructor, a tenured associate professor with nine years of college service, was the course's sole instructor prior to flipping (2016 – 2018), designed the flipped course in 2019, and remained the course's sole instructor after flipping. Having served on the college's Online Education Subcommittee and taught and designed several fully online courses, the instructor is an expert in Blackboard and the department's main contact for everything online education-related. This is important since, under the flipped format, the new material that students learn at home is organized and communicated by the instructor in the Blackboard learning management system. The instructor's own positive experiences as a student in flipped college classrooms drive the instructor's enthusiasm for this active-learning strategy. The instructor is a fan of, and skilled at Socratic-type questioning and is comfortable calling on students who do not volunteer themselves, patiently waiting in silence (sometimes ten or more seconds!) for students to gather their thoughts and respond to questions. These qualities were necessary for in-class activities to promote higher-level student learning and elicit participation from all.

3: Analysis

Teaching methodologies such as the flipped classroom method can impact students both grade-wise (e.g., how well did students perform on tests in the flipped classroom versus in standard classrooms?) and emotionally (e.g., what do students perceive the net gain of the flipped classroom to be? How excited are students to participate in the flipped classroom versus the standard classroom?) Easy to overlook, the latter is important since student's emotional experiences can impact their ability to learn, their engagement in school, and their career choices [6]. Additionally, even students who understand the material may not be good test-takers. License students—who are of particular interest to this study—may respond differently than intern students in both regards. Accordingly, the current study aims to describe the effects on both student grades and emotions by providing a quantitative analysis of student scores and a qualitative discussion of results from surveys completed by students in the course.

3.1: Grade impact measurement

Quantifying exactly how much a student understands the course material is difficult. The author chose to use final course grades as the measure of student understanding, since this single measurement encompasses the student's performance over all of the course material, has been carefully calibrated by the seasoned instructor, and is easily obtained from school records for both license and intern students. In order to estimate the effect that classroom flipping had on students' grades in the course, the popular DiD method was employed. In DiD analysis, data are collected in a "pre-treatment" period (i.e., before flipping) and a "post-treatment" period (i.e., after flipping) in both the treated course (ENGR 383 Signals and Systems) and a control course that was not flipped during the same time period. First, convert letter grades to numerical grades using the conventional mapping used to calculate Grade Point Average (GPA) shown in Table 1 (note that 'A+' and 'D-' are never assigned at the college.) Then, define the gain of the treated course to be

$$G = x_{post} - x_{pre}$$

where x_{pre} and x_{post} are the numerical course grades in the pre- and post-treatment datasets, respectively, averaged across all students in the datasets. Similarly define the gain of the control course to be

$$\hat{G} = \hat{x}_{post} - \hat{x}_{pre}$$

TABLE 1: Conventional grade mapping letter grades to numerical grades.

A	**A-**	**B+**	**B**	**B-**	**C+**	**C**	**C-**	**D+**	**D**	**F**
4.00	3.67	3.33	3.00	2.67	2.33	2.00	1.67	1.33	1.00	0

Then, the DiD test statistic β is the difference

$$\beta = G - \hat{G} \quad (1)$$

The idea is that $\hat{G}$ represents the gain the treated course *would have seen* had it not been flipped and accounts for the variability of student performance that occurs by chance. This concept—the "parallel trend assumption"—and how it can project the performance had treatment not taken place is illustrated in Figure 1 and is key to DiD analysis. Thus, the difference in Equation (1) yields the numerical effect flipping the classroom had on final grades. The parallel trend assumption is a reasonable one with an appropriately selected control course.

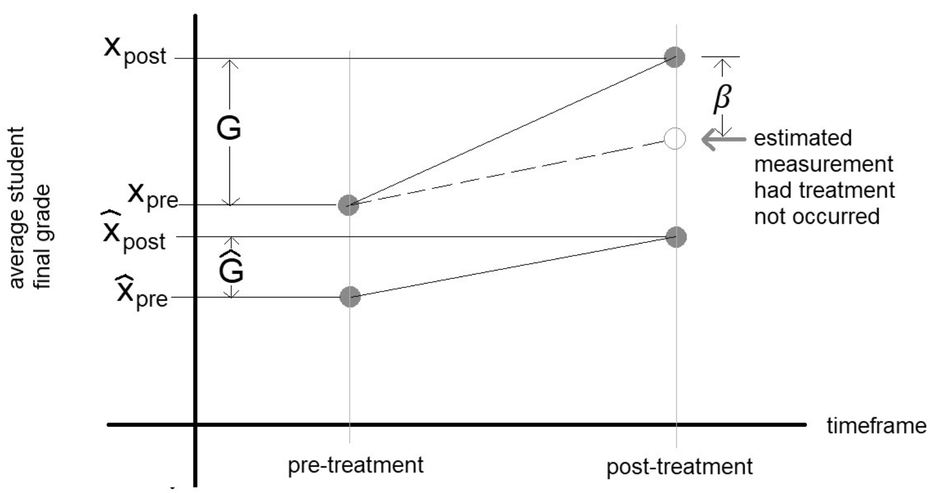

FIGURE 1: Parallel trend assumption used in DiD analysis.

Taught by the same instructor to the same group of students during the same semester (fifth-semester electrical engineering intern and license students), ENGR 394 Electromagnetic Fields served as the control course. Like the treated course, ENGR 394 is a required three-credit theoretical course that is mathematically intensive. Both courses share the same pre-requisite of differential equations. Homework and exam problems from both courses almost always require many mathematical steps progressing in a logical manner, with the student earning partial credit along the way. With a correlation of 0.782, a student's final numerical grade in one course is a good indicator of the final numerical grade in the other course, as illustrated in Figure 2. Thus, the difference in Equation (1) subtracts out any net effects that would be due simply to a new year with a new group of students having different levels of preparedness and abilities compared to the year prior, since any new group of students generally takes both the treated and the controlled course, and performs similarly in both courses.

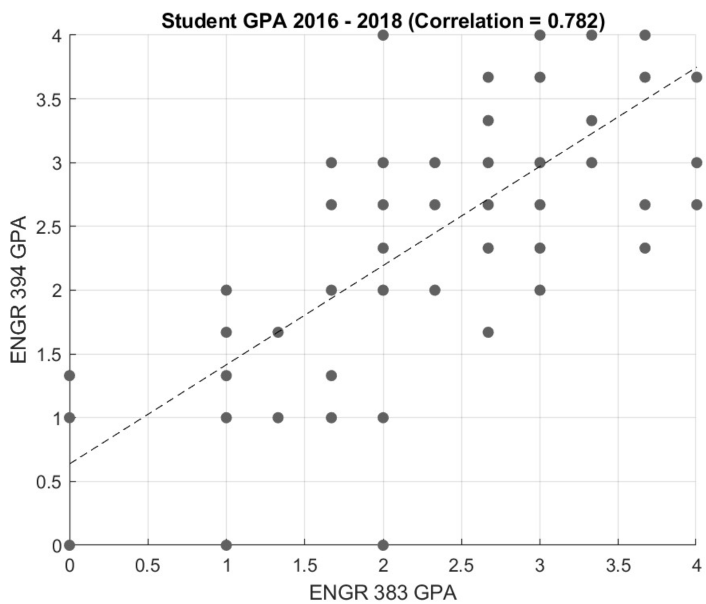

FIGURE 2: Scatter plot of student grades ENGR 394 versus ENGR 383 during the pre-treatment period.

Final course grades were retrieved for intern and license students in both courses for three years prior to flipping, years 2016-2018. The pre-treatment period of Figure 3 shows the approximately parallel trends in the two courses for three datasets: license, intern and all students. Most pronounced in the license student dataset, Figure 3 makes it clear that students generally performed worse in ENGR 383, and that the course grades were trending downwards—two concerns which prompted the instructor to move away from the traditional classroom approach in favor of flipping.

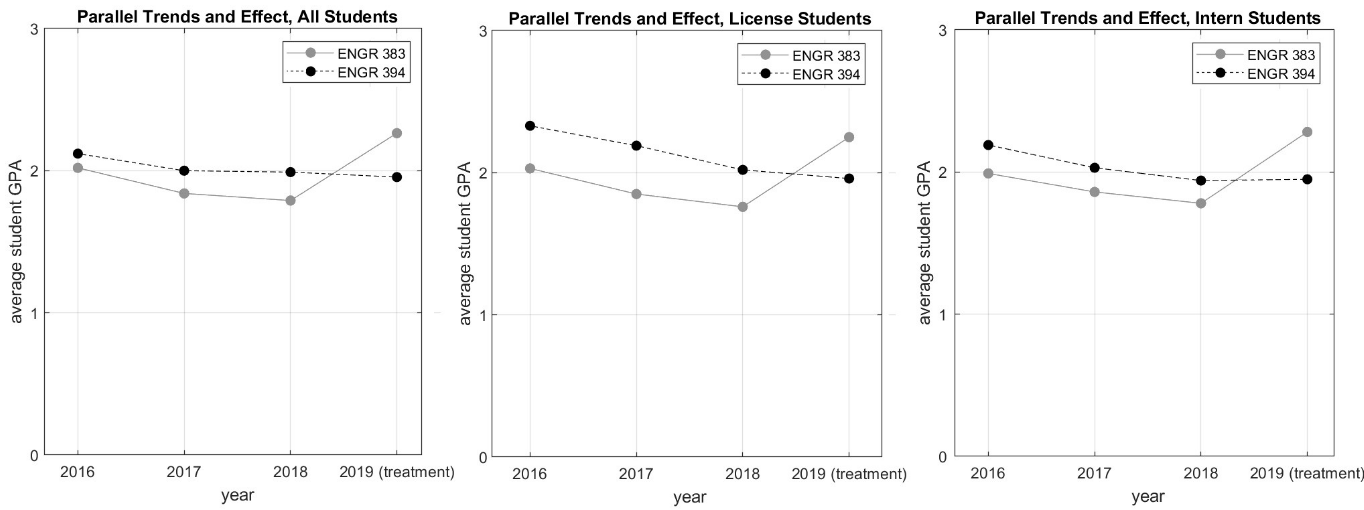

FIGURE 3: The trends of ENGR 383 and ENGR 394 are approximately parallel prior to treatment. The trend of the flipped course ENGR 383 deviates from the trend of the control course ENGR 394 in the year the course was flipped (2019) in each of the three datasets.

3.2: Perspective and attitude impact survey

Both license and intern students were asked to complete a course survey custom-made by the instructor with the sole purpose of gauging students' perspective and attitude as pertaining specifically to the flipped format. Students were asked to complete the survey in Figure 4 after taking each of five exams throughout the semester, thereby providing insight into how students' perspectives changed as the course progressed. This is important since students can often initially perceive the flipped format negatively, believing it to be too difficult to learn at home, too much work, or just a fad that has no real impact [1]. It is of interest then to observe how long it takes students with these negative perspectives to change them, if ever, while also observing differences in perspectives between license students and intern students, if any.

The survey was partitioned into three sections. The purpose of Section I, with only one question **Q 1.1** (referencing Figure 4), was to acquire the necessary information to separate the surveys into the license and intern datasets while preserving student anonymity. The purpose of Section II of the survey was to understand students' perspectives and attitudes of the learning process in general as related to classroom flipping. The purpose of Section III was to understand the students' perspectives specifically in ENGR 383, especially regarding ABET and course learning objectives. For example, **Q 3.2** was directly tied to ABET Criterion (1). Both **Q 3.3** and **Q 3.4** are directly tied to course learning objectives.

Except for **Q 1.1** (a yes-no question), all of the questions required the student to circle either *SA* (Strongly Agree), *A* (Agree), *N* (Neutral), *D* (Disagree), or *SD* (Strongly Disagree). Having to complete the survey immediately after taking an exam, students were in a prime state of mind to accurately reflect on their learning.

ENGR 383 SIGNALS AND SYSTEMS CLASSROOM SURVEY Date: XX/XX/XXXX

As you know, your instructor has decided to abandon traditional lecture-based teaching in favor of a more active approach. Your completion of this survey helps with the planning of such a course moving forward. In the following, "flipped" refers to this active approach, which is the format of watching instructor videos at home and completing problems with your instructor and peers in class. *<u>Circle exactly one choice for each question</u>.*

SECTION I.			
Q 1.1	I am a license student.	Yes	No

KEY: SA = Strongly Agree A = Agree N = Neutral D = Disagree SD = Strongly Disagree

SECTION II.						
Q 2.1	The format of traditional lecture-based engineering courses is in need of reform.	SA	A	N	D	SD
Q 2.2	I can learn any complex engineering subject matter—at least the basic ideas—at home when the instructor provides me a clear path for doing so with, for example, sequenced videos, readings, technology, etc.	SA	A	N	D	SD
Q 2.3	It is beneficial to my learning to be able to solve problems in the presence of the instructor.	SA	A	N	D	SD
Q 2.4	It is beneficial to my learning to be able to solve problems with my peers.	SA	A	N	D	SD
Q 2.5	I learn better in a hands-on environment.	SA	A	N	D	SD

SECTION III.						
Q 3.1	I would prefer ENGR 383 be taught in the traditional lecture-based format.	SA	A	N	D	SD
Q 3.2	More so than had it been lecture-based, the flipped format of ENGR 383 promotes identifying, formulating, and solving complex engineering problems by applying engineering, science, and mathematics.	SA	A	N	D	SD
Q 3.3	My knowledge of signals and systems is more in-depth than what it would have been had the course been a traditional format.	SA	A	N	D	SD
Q 3.4	The flipped format of ENGR 383 promotes the development of my math skills more so than had the course been of a traditional format.	SA	A	N	D	SD
Q 3.5	My current course grade in ENGR 383 would probably be lower if the course had been a traditional format.	SA	A	N	D	SD
Q 3.6	More so than in my traditional lecture-based engineering courses, I am engaged in learning the ENGR 383 course material.	SA	A	N	D	SD

FIGURE 4: Flipped classroom survey used in ENGR 383.

4: Results

Final course grades were collected from 92 students who completed both ENGR 383 and ENGR 394 in the three years prior to flipping (2016—2018). This group of 92 students was comprised of 40 intern students and 52 license students. The final course grades of the 29 students who completed ENGR 383 in 2019—when it was flipped—and additionally the control course ENGR 394 in the same year were also collected. This group of 29 students was comprised of 13 intern students and 16 license students. The data were arranged into the three datasets *intern*, *license*, and *all* students, and analyses were conducted on all three of them.

As listed in Table 2, DiD analysis shows that both license and intern students enjoy a positive gain in the flipped classroom. Interestingly, license students see a larger gain in GPA ($\beta = +0.583$) than do intern students ($\beta = +0.474$). All students enjoy a gain of $\beta = +0.534$ The gain is obvious in Figure 3 in which the trend of ENGR 383 clearly deviates from the trend of ENGR 394 in the year that ENGR 383 was flipped, in all three datasets. From the figure, students in all three datasets actually performed better on average in ENGR 383 than they did in the control course—the first time in the four-year timeframe. Also from Figure 3, license students overcame a much wider gap between the two courses than did intern students, an observation that is captured in the relatively large effect measured on the license student dataset.

TABLE 2: Observed gain in GPA resulting from the flipped classroom. Statistical significance is also shown.

	license students	intern students	all students
GPA gain (β)	+0.583	+0.474	+0.534
p-value	0.006	0.032	< 0.001
confidence at 95% ?	YES	YES	YES
confidence at 99% ?	YES	NO	YES

Of course, the possibility exists that the gain in GPA happened by chance—that maybe the students in 2019 were, for some reason, unusually well prepared for ENGR 383 but not for ENGR 394. It was pertinent to the study, then, to test for statistical significance. Considering the null hypothesis to be that flipping the classroom had absolutely no effect on students' final course GPA, this study applied the method of random inference [8] in order to estimate the probability of observing at least the measured gain under the condition that the null hypothesis is true. To this end, each of the three datasets were randomly and separately sampled without replacement with student records being reassigned the tag of "pre-treatment" or "post-treatment", making sure to keep the pre- and post-treatment data sizes equal to the original. For example, if a student was randomly chosen to be part of the pre-treatment cohort, then this student's final grades in both ENGR 383 and ENGR 394 were considered to have occurred prior to 2019. Only license students were sampled to create a new random license dataset; only intern students were sampled to create a new random intern dataset. For each of the three random datasets (including all students), the observed DiD test statistic was recorded and compared against that of the true (i.e., nonrandom) dataset. This process was repeated 1000 times, and the fraction for which the DiD test statistic of the random dataset was larger than that of the true dataset was recorded in Table 2 as the p-value. From this table, it can be seen that only six in 1000 tries did the test statistic of the random license dataset exceed that of the true license dataset. With a corresponding p-value of less than 0.01, there is at least 99% confidence that license students benefitted from the flipped classroom with the observed gain in GPA.

Interestingly, Table 2 shows that there was not the same high confidence in intern students as there was for license students. For interns, the observed test statistic for the randomized data was larger than that of the true dataset 32 out of 1000 tries, corresponding to a p-value of 0.032. Therefore, it cannot be said with 99% confidence that interns benefitted from the flipped classroom with their observed gain in GPA.

All 29 students completed the course survey five times as the course progressed, once after each course exam. The results from the survey after each exam are shown in their entirety Tables 3 through 5. Somewhat shockingly, students strongly believed that the traditional lecture-based method of teaching is in need of reform, as evidence by their responses to **Q 2.1.** Ten out of 16 license students either agreed or strongly agreed with **Q 2.1** after the first exam in the course, which roughly occurs one-fifth of the way through the course. This number grew to 15 out of 16 at the conclusion of the course. Only two intern students of 13 felt the same as their license student counterparts after the first exam. But this number tripled to six out of 13 at the conclusion of the course.

TABLE 3: Tabulated survey responses from license students after each of five exams (E).

		Q 2.1	**Q 2.2**	**Q 2.3**	**Q 2.4**	**Q 2.5**	**Q 3.1**	**Q 3.2**	**Q 3.3**	**Q 3.4**	**Q 3.5**	**Q 3.6**
	SA	3	0	10	4	3	1	1	1	2	2	3
	A	7	2	4	8	10	3	4	4	4	1	7
E1	**N**	5	12	1	1	3	9	9	9	8	11	2
	D	1	1	1	2	0	3	2	2	2	2	1
	SD	0	1	0	1	0	0	0	0	0	0	3
	SA	3	0	11	4	4	0	4	4	4	4	4
	A	8	1	4	8	9	3	3	3	4	2	6
E2	**N**	5	13	1	1	3	10	8	8	8	10	2
	D	0	1	0	2	0	2	1	1	0	0	2
	SD	0	1	0	1	0	1	0	0	0	0	2
	SA	3	1	11	4	4	0	5	5	5	3	5
	A	9	2	4	8	10	0	4	4	5	3	5
E3	**N**	4	12	1	1	2	10	6	6	6	10	3
	D	0	1	0	1	0	2	1	1	0	0	1
	SD	0	0	0	2	0	4	0	0	0	0	2
	SA	4	1	12	3	5	0	6	6	6	3	5
	A	10	3	4	9	10	1	5	5	6	3	7
E4	**N**	2	12	0	1	1	6	4	4	4	10	2
	D	0	0	0	1	0	4	1	1	0	0	1
	SD	0	0	0	2	0	5	0	0	0	0	1
	SA	5	1	11	3	5	1	6	6	6	3	6
	A	10	4	5	9	11	1	6	6	7	3	6
E5	**N**	1	11	0	1	0	3	3	3	3	10	2
	D	0	0	0	1	0	6	1	1	0	0	1
	SD	0	0	0	2	0	5	0	0	0	0	1

TABLE 4: Tabulated survey responses from intern students after each of five exams (E).

		Q 2.1	Q 2.2	Q 2.3	Q 2.4	Q 2.5	Q 3.1	Q 3.2	Q 3.3	Q 3.4	Q 3.5	Q 3.6
E1	**SA**	1	1	6	2	3	1	1	1	1	1	1
	A	1	1	4	2	7	5	3	3	4	1	3
	N	8	10	1	6	1	5	6	6	6	9	6
	D	3	1	2	1	2	2	2	2	1	1	2
	SD	0	0	0	2	0	0	1	1	1	1	1
E2	**SA**	1	1	6	2	2	1	1	1	1	1	2
	A	1	1	5	2	7	4	5	5	6	3	5
	N	7	9	1	6	2	5	5	5	4	8	4
	D	4	1	1	1	2	3	2	2	2	1	2
	SD	0	1	0	2	0	0	0	0	0	0	0
E3	**SA**	1	2	5	2	2	2	2	2	2	2	3
	A	2	2	6	3	8	5	4	4	5	2	4
	N	6	8	1	5	1	1	4	4	3	8	4
	D	4	1	1	2	2	4	3	3	3	1	2
	SD	0	0	0	1	0	1	0	0	0	0	0
E4	**SA**	2	2	5	2	3	1	2	2	2	2	3
	A	2	2	6	3	8	5	5	5	6	2	5
	N	5	8	1	5	0	2	3	3	2	8	3
	D	4	1	1	2	2	4	3	3	3	1	2
	SD	0	0	0	1	0	1	0	0	0	0	0
E5	**SA**	3	2	6	1	4	1	2	2	2	2	3
	A	3	2	5	4	7	5	6	6	7	4	6
	N	5	8	1	6	0	1	2	2	1	6	2
	D	2	1	1	1	2	5	3	3	3	1	2
	SD	0	0	0	2	0	1	0	0	0	0	0

TABLE 5: Tabulated survey responses from all students after each of five exams (E).

		Q 2.1	Q 2.2	Q 2.3	Q 2.4	Q 2.5	Q 3.1	Q 3.2	Q 3.3	Q 3.4	Q 3.5	Q 3.6
	SA	4	1	16	6	6	2	2	2	3	3	4
	A	8	3	8	10	17	8	7	7	8	2	10
E1	**N**	13	22	2	7	4	14	15	15	14	20	8
	D	4	2	3	3	2	5	4	4	3	3	3
	SD	0	1	0	3	0	0	1	1	1	1	4
	SA	4	1	17	6	6	1	5	5	5	5	6
	A	9	2	9	10	16	7	8	8	10	5	11
E2	**N**	12	22	2	7	5	15	13	13	12	18	6
	D	4	2	1	3	2	5	3	3	2	1	4
	SD	0	2	0	3	0	1	0	0	0	0	2
	SA	4	3	16	6	6	2	7	7	7	5	8
	A	11	4	10	11	18	5	8	8	10	5	9
E3	**N**	10	20	2	6	3	11	10	10	9	18	7
	D	4	2	1	3	2	6	4	4	3	1	3
	SD	0	0	0	3	0	5	0	0	0	0	2
	SA	6	3	17	5	8	1	8	8	8	5	8
	A	12	5	10	12	18	6	10	10	12	5	12
E4	**N**	7	20	1	6	1	8	7	7	6	18	5
	D	4	1	1	3	2	8	4	4	3	1	3
	SD	0	0	0	3	0	6	0	0	0	0	1
	SA	8	3	17	4	9	2	8	8	8	5	9
	A	13	6	10	13	18	6	12	12	14	7	12
E5	**N**	6	19	1	7	0	4	5	5	4	16	4
	D	2	1	1	2	2	11	4	4	3	1	3
	SD	0	0	0	4	0	6	0	0	0	0	1

Also interesting are the student responses to **Q 2.2**, for which 22 students out of 29 responded neutrally after the first exam, and only four either agreed or strongly agreed. The neutral responses, however, seemed to redistribute to agree or strongly agree slowly during the semester. After the third exam, 20 students responded neutrally, and seven either agreed or strongly agreed. After the fourth exam, eight students either agreed or strongly agreed. And after the course's conclusion, 19 students responded neutrally, and nine students either agreed or strongly agreed. Only a single student disagreed.

Q 3.2 related to the course's lone ABET learning outcome. Early in the course—after the first exam—only five out of 16 license students and two out of 13 intern students believed the flipped format promotes identifying, formulating, and solving complex engineering problems more so than would the traditional lecture-based format. About midway through the course, those numbers grew to nine and six, respectively. At the end of the term, 12 license students and eight interns representing 70% of the class either agreed or agreed or strongly. These results supported the observed change in sufficiency rate of the ABET criterion assessed by the course instructor, which increased from 65% in years prior to flipping to 75% post-flipping.

Both **Q 3.3** and **Q 3.4** related to the course learning objectives and their results followed a similar pattern to the results of **Q 3.2**. Only five and six license students either strongly agreed or agreed to **Q 3.3** and **Q 3.4**, respectively. These numbers increased to 11 and 12 respectively at the end of the course. Similarly, four (**Q 3.3**) and five (**Q 3.4**) interns agreed or strongly agreed initially, and 8 and 9 interns strongly agreed or agreed at the course's conclusion.

5: Discussion

The instructor made the effort to keep expectations, rigor, and grading consistent in ENGR 383 before and after the flipping process, although keeping the exact same grading scheme was impossible due to the differences in the assessments demanded of each format. Final grades in the traditional course prior to flipping were calculated with homework (15%), a project (25%), two equally weighted mid-term exams (30% total), and a final exam (30%). In the flipped format, 22 equally weighted quizzes (18.75%) played the role of homework. With unlimited opportunities, almost all students achieved perfect grades on quizzes, just as they often do on homework. In the flipped format, participation (25%) was no "gimme" and played the role of the project. Both required the students to work with their peers, apply their knowledge, and communicate their findings. Students in the flipped format scored roughly the same on participation as prior students did on the project. Lastly, the flipped format had five equally weighted exams (56.25% total) which asked similar questions as the exams in the traditional format. It was the exam scores that saw a huge positive difference in student performance, and they were the reason students had a positive gain in GPA. Obviously, students were better able to apply what they learned from class on the exams, especially the license students.

License students prefer working in hands-on environments and with their peers. This is made evident by their responses to **Q 2.5**, which zero license students disagreed from early on in the course. (Note: for brevity in this section, "disagreed" means disagreed or strongly disagreed, similar for "agreed.") At the author's school, license students spend much of their time on the training ship, in laboratory and welding classes, and in ship simulators—making it no surprise they prefer hands-on instruction. Related, license students believe they learn better when they can work out problems with their peers and with the instructor, as is made clear by their responses to **Q 2.3** and **Q 2.4.** The majority of license students agreed with these two questions from very early on in the course. The flipped classroom, of course, *is* a hands-on environment that promotes problem solving, reasoning, and Socratic-type questioning with peers and the instructor. One might infer, then, that license students are more open to the idea of a flipped classroom, except that it appears license students are not confident in their abilities, as evidenced by responses to **Q 2.2**.

Most license students' responses to **Q 2.2** were neutral—indicating they are not sure if they can succeed in the flipped classroom. But interestingly, the number of students who agreed with that question increased from two after the first exam to five at the course's conclusion. Students became more confident in their abilities, the author believes, for two reasons: The first is that traditional lecture-based engineering courses never even offered students the opportunity to learn complex engineering subject matter at home, so naturally students improve with first experience in the flipped course. Secondly, students get the opportunity to reinforce what they have learned at home since instructor/peer interaction in the classroom is the *second* time the students are contemplating the material, allowing them to get deeper into the material and build confidence. Still though, by the end of the course, 11 license students were neutral to Question **Q 2.2**. The reason may be that students doubt that every engineering course can be flipped, even though ENGR 383 may have been successful. The results from Question **Q 3.1** distinguish students' general opinion from their specific opinion of ENGR 383.

Four license students agreed and three disagreed with this question after the first exam, which slightly disfavors the flipped format. But the distribution shifted dramatically towards favoring the flipped format as the course progressed. After the third exam, for example, which is roughly the middle of the course, six license students agreed with the question and none disagreed. At the conclusion of the course, 11 students disagreed and only two agreed. License students learned to favor the flipped format—they became open to the idea of introducing themselves to the material on their own as long as they had the chance to discuss the material with their instructor and peers. Intern students, on average, perceived the flipped format much differently, and a reasonable fraction of them were against it from the beginning of the course, persisting through the course's conclusion. For example, six of 13 thirteen interns agreed with **Q 3.1** after the first exam, and only two disagreed. At the course's conclusion, the numbers persisted with six students still agreeing with the question.

Clearly, license students have a propensity to learn in the flipped classroom format, a conclusion further supported by the results from the DiD analysis. The gain in GPA that license students saw on average was $\beta = +0.583$. On a 4.00-grading scale, where letter dressings (e.g., '+' and '-') contribute one-third of a GPA point, the observed gain is almost two letter dressings of improvement. For example, one license student may have earned a 'B+' in the flipped format when he would have earned a 'B-' had the course been of a traditional format. For some students, this could mean the difference of passing or failing the course. While intern students also saw a boost in GPA ($\beta = +0.474$), the gain was closer to a single letter dressing, for example, a 'B' instead of a 'B-'. The reason for this discrepancy is unclear. It could be that license students benefitted from the flipped format because their abundance of opportunities to work in hands-on learning environments have made them bored of the traditional format. Conversely, interns'—with their limited exposure to hands-on learning environments—may have become conditioned to the traditional format and learned to survive in it, as boring as they may find it.

6: Conclusion

Focusing on final course grades and student perspective, this paper investigated the impact that the flipped classroom pedagogy has on U.S. Coast Guard license students by comparing their final course grades in a flipped engineering course with their final course grades in traditional engineering courses, and by tracking their responses to course surveys given throughout the duration of the flipped course. Regarding student perspective, license students believed at the onset of the course that traditional lecture-based classrooms were in need of reform, and they doubled-down on those beliefs in favor of the flipped course as the flipped course progressed. The license students perceived the gains in their learning to be more in the flipped classroom than if the course had been taught in a traditional format. They favored the flipped classroom format more than their non-license student counterparts. With regards to final course grades, license students saw a boost of +0.583 in GPA, which was more than non-license students, who still enjoyed a gain of +0.474 in GPA. A discussion was provided that tied both impacts together and explained the observed results.

This study has several limitations. Aggregating the data (survey results and final course grades) of all license students together makes it impossible to study which students benefited from the flipped format more than others, or if the benefits were distributed uniformly across all students. For example, it would be interesting to learn if lower-performing license students (i.e., those entering the course with a low GPA) benefitted more or less than higher-performing license students. The methods in this paper could be applied to such a study using subsets of students grouped by their GPA. Such a study, however, would demand a large class size or several years of data in order to create subsets large enough for statistical significance. Further limiting the current study is its one-time use of course grades to measure grade impact. Ideally, grade impact would be measured throughout the duration of the course instead of only at its conclusion, allowing the instructor to better allocate time and resources as necessary. At the time of the study, there had been no attempt to correlate the flipped classroom format with the students' pass rate of the U.S. Coast Guard License Exam. It is expected that flipping only one class would not have a significant impact on this rate, since the license exam is a comprehensive exam that covers many different facets of maritime engineering education. Despite these limitations, the results of the study are encouraging. The author plans to flip more courses in the future and measure the impact, making the results of this type of study more reliable. With more data and more results in favor of the flipped classroom format, it is the hope of the author that the department would consider flipping other license courses.

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