# Classroom Modality Comparison for Team-Taught Statics

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# Team-Taught Statics


## Abstract

Organizing classroom structure is a primary job for each instructor. In this work we present a comparison of five different sections of an Engineering Statics class over the course of the Fall 2024 semester in the Mechanical and Aerospace Engineering Department at NC State University: 1) and 2) MWF flipped class (at 8:30 and at 9:35 AM), 3) MW flipped class w/some lecture, 4) a T-Th lecture class, and 5) a distance section offered MWF at 8:30 with mostly nontraditional students. All three classes use common exams (three plus a final) and weekly quizzes. The exams are primarily auto-graded except for a small amount of hand grading for free-body diagrams for the first and second exams.The goal of this work is to compare outcomes of the same class being taught flipped, hybrid, and lecture, and observe how it affects student performance and engagement.

In previous semesters, students were only allowed one attempt on the weekly quizzes, but in this team-taught semester students were allowed two attempts to determine if any extra study time spent on a second attempt would improve their quiz and exam scores. Weekly quizzes use pre-programmed problems with algorithmically generated values to provide variety to each student's attempt. The quizzes also allow students to review the attempt with minimal feedback later but do not provide numerical or step-by-step solutions.

The study did not show any clear indication that one teaching modality was more-highly correlated with student performance than any other.


## Introduction

Between 2008 and 2023, Statics at NC State has been taught during Fall and Spring semesters exclusively by Dr. Anna Howard (instructor A). The growing department has made it impossible for any individual instructor to teach all the students we have. As more instructors were added to the teaching rota, we had the unique opportunity to examine how different teaching styles impacted student outcomes.

During Fall 2024, three people taught Statics: instructor A (Anna Howard) who had been teaching all the sections fall-and-spring during 2008 - 2022, instructor B (Greg Watkins) who was new to NC State University but with 29 years of prior teaching experience, and instructor C (Nicholas Garcia) who was a graduate student and a teaching mentee for instructor A with significant familiarity with the flipped class and materials.

All instructors agreed to use the same weekly quizzes and exams. These exams are created and administered via our learning management system Moodle. Weekly quizzes included questions such as the equilibrium of a beam shown in Figure 1 [1, 2]. Multiple questions were asked about this problem: First, the free-body diagram (FBD) was submitted by students to Gradescope and was

graded by the TAs. A multiple-choice question asked students what their FBD was of, specifically what the body was. The question algorithmically generated values for *a* so that student answers varied. (Some questions on the weekly quizzes had as many as 12 variables all of which varied.) Students entered the reactions they calculated at A and D using the variables they were assigned.

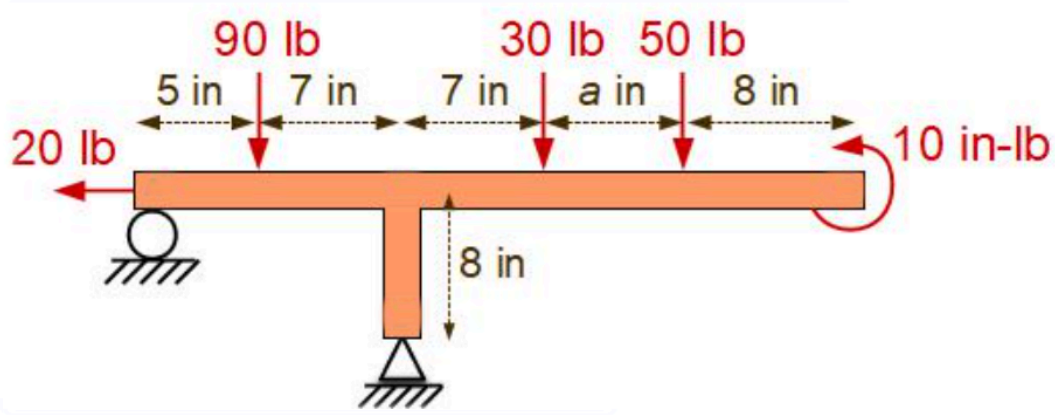



***Figure 1.*** *Two-Dimensional Beam Equilibrium Problem from Weekly Quiz*

Partial credit was awarded only sparingly for the weekly quizzes. Averill et al showed that students could graduate with engineering degrees having gotten few if any problems fully correct [3]. These weekly quizzes were used to encourage students to discover working habits that allow them to get the answers right. For example, instructor A commonly had office hour visits during which students discovered the value of working early and checking the calculator answers; instructor B noted with frustration that office hours were rarely about the topics but instead about finding student errors in the quiz answers.

Unlike the weekly quizzes, the exam questions were graded with significant partial credit. The exam version of a 2-D beam equilibrium problem is shown in Figure 2. For both the weekly quiz and the exam, students entered their answers in blanks but students were prompted not to leave out the units by having the question use pull-downs for units. The midterm exams awarded more partial credit than the weekly quizzes. For example, students who mistook cosine for sine or had a sign error which could be identified in advance were given appropriate partial credit. Students who received no credit but had a common error could contest their score by providing the correct solution and the solution they had followed with an explanation of why their error had been trivial: regrades were applied to the entire student population in Statics.

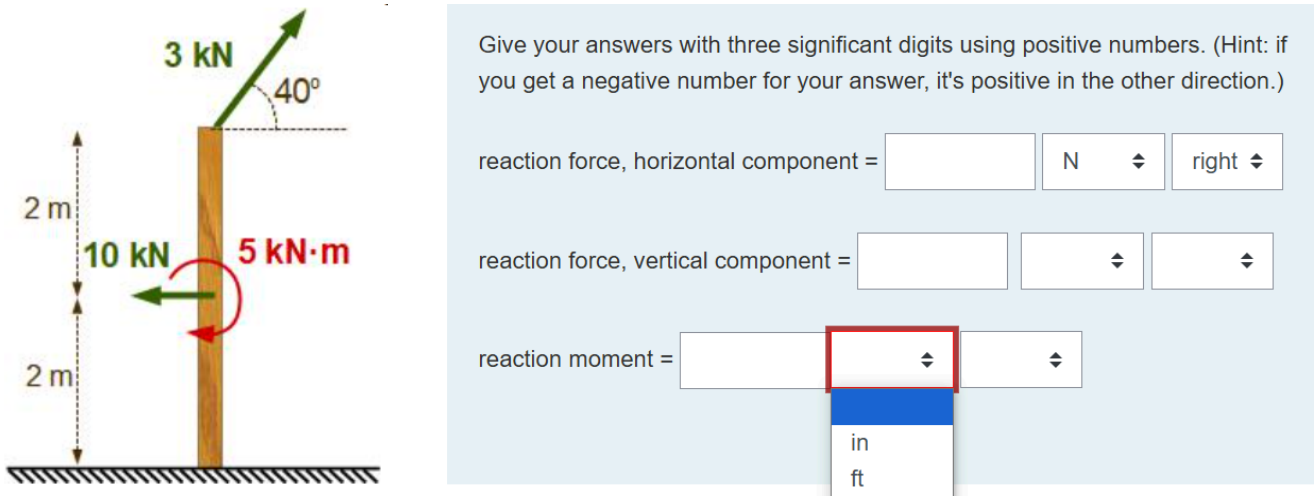



***Figure 2.*** *Two-Dimensional Beam Equilibrium Problem from Midterm Exam*

## Description of Classes

The flipped and distance classes were taught by instructor A. Instructor B used traditional lecture with occasional in-class exercises to engage students in active learning. Instructor C utilized a partial-flip characterized by one or two 10-15 minute mini-lectures that focused on some of the more challenging problems from the slides. The grade breakdowns used by each instructor are shown in Table 1.

***Table 1.*** *Grade Breakdown by Instructor*

| *Course element* | *Instructor A* | *Instructor B* | *Instructor C* |
|---|---|---|---|
| *Weekly quizzes* | *17%* | *25%* | *10%* |
| *Midterm exams (3)* | *13%* | *45%* | *15%* |
| *Final exam* | *22%* | *30%* | *25%* |
| *Projects* | *10%* | | *15%* |
| *Preparation quizzes* | *6%* | | *5%* |
| *Class participation* | *6%* | | |

Instructor A taught a full-flipped class for sections 1, 2, and the distance education section. This class involves short concept videos with a short quiz for students before each class. These sections include practice quizzes which are optional but serve to improve weekly quiz grades for students who take them. No on-paper homework was assigned and attendance was taken [2-4, 5]. During class, students worked in assigned groups of three with a single white board and only one marker to encourage them to work together. Groups could proceed at their own pace using slides available on Google to all the students. The class participation grade in Table 1 is only achievable for students

who were actually present in class. Projects were based on several cards from Engineering Unleashed and included open-ended real-world applications for the students [6, 7].

Instructor B taught in a traditional lecture format. Due to the size of the class (115 students), writing on the board was not practical. Slides were developed with basic theory, equations, and images to convey the topics. The slides were provided to the class ahead of time. Slide decks also included examples that provided only the problem statement and picture/image. Blank spaces were provided for working through the problems. The instructor showed the slides through a Microsoft Surface tablet. A stylus was utilized to "write" on the slides and work through the example problems. After one or two examples were worked by the instructor, a "your turn" example was shown. Time was allowed in class for students to work through the problem themselves. They were encouraged to work together in small groups but this was not a requirement. Their in-class work was not collected or graded and no credit was given for participation or for attending class. After ample time was provided for the students to work the problem, the instructor worked it out on the tablet, allowing students to either confirm their approach and correct answer, or see where they made mistakes. The institution automatically records all classes so students could go back and review the instructor's examples and solutions if needed.

Instructor C taught a partially flipped class. The same videos, quizzes, exams, and projects were used from Instructor A's course, but different course percentages were applied as outlined in Table 1 above. It was a two-day course, and met on MW for 75 minute classes. Additionally, attendance, in-class teams, and peer evaluations were not required. Instructor C used small lectures within the flipped class time in an attempt to restore class engagement and resolve misconceptions, particularly of those students who tend to isolate themselves from the rest of the class. The class was approximately 70/30 percent flipped/lecture. During class time, the instructor would discuss one or two preselected problems and provide a walkthrough. These problems were from the lecture slides covered in class that day. Usually 15-25 minutes was allowed for working the problem and answering student questions. It should be noted that the solutions to the challenging problems were already given on the slides and in fuller detail on a website managed by Instructor A. Instructor C only took some extra time to slow the class pace and focus on the challenging problems to address potential pitfalls.

## Limitations

Enrollment at NC State University is opened to students on a rolling basis based on their credits earned and current GPA. Students from high schools where there were many AP courses generally have more credits and get their options of classes before others. Our courses were spaced as shown in Table 2.

***Table 2.*** *Sections, times offered, and number of students enrolled at the time of the first exam*

| Section | Instructor | Time of Delivery | Number of students who took the first exam |
|---|---|---|---|
| 1 | Howard | 8:30 - 9:20 am Monday-Wednesday-Friday | 106 |
| 2 | Howard | 9:35 - 10:25 am Monday-Wednesday-Friday | 85 |
| 3 | Watkins | 8:30 - 9:45 am Tuesday-Thursday | 111 |
| 4 | Garcia | 4:45 - 5:30 pm Monday-Wednesday | 111 |
| Distance | Howard | 8:30 - 9:20 am Monday-Wednesday-Friday | 17 |

Students who wanted to avoid an 8:30 am class were more likely to fill one of the other sections first leading to inequities in preparation and ability between the sections. The authors had no ability to access grades for the prerequisite courses in Physics and Calculus which could have served as a statistical adjustment. Future work could consider these adjustments. Class sizes were also different, though the biggest difference was the distance section which also included a higher percentage of returning students than the normal population of students at NC State University.

To compare one section with another, the weekly quiz and exam scores were binned into 90 - 100, 80 - 89.999, etc. for each section. For each result, the percentage shown is taken out of the number of students with non-zero results on that quiz without regard to whether or not the student finished the class (not the total number of students in the class).

We present the midterm exam comparisons in full with a brief discussion of weekly quizzes and a final discussion of the semester grades.

## Results

First we compared the section grades for Exam 1. This exam is given at the end of week 3. Exam 1 covers forces and particle equilibrium in 2- and 3-dimensions. The grade comparison for Exam 1 across the sections is shown in Figure 3. Significant differences are seen between the sections. However, looking at the students getting B’s on the exam (for example), the biggest differences are not between the modalities. Instructor A taught the blue, red, and orange sections in Figure 3; these were all flipped sections. Instructor B’s class is in yellow, instructor C’s class in green.

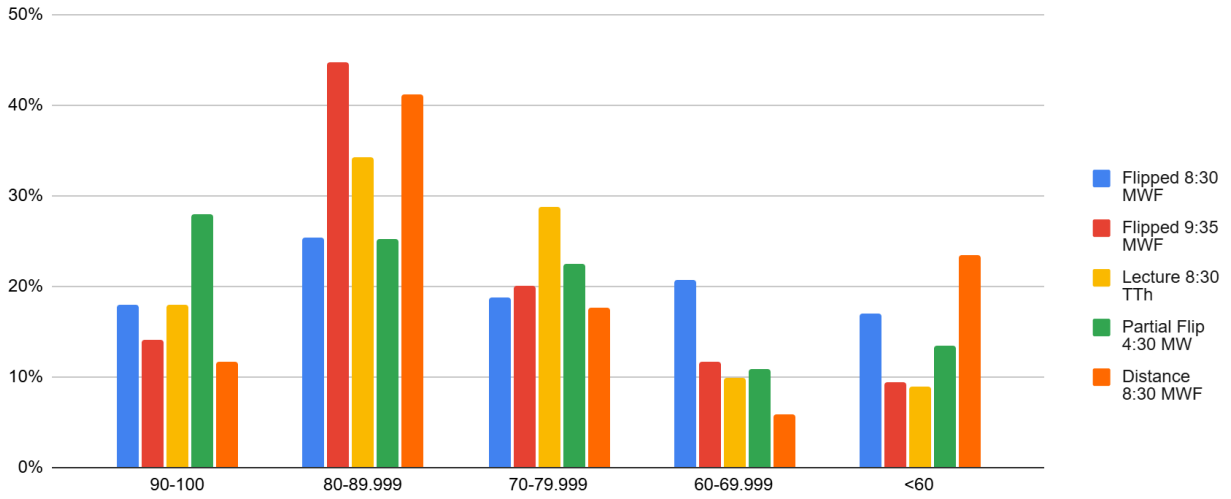



**Figure 3**. *Grade comparison for Midterm Exam 1*

The differences between one section and another do not correlate for exam 1 with the modality used by the instructor.

For exam 2, the Tuesday-Thursday lecture class had two students drop out and not take exam 2. The partial flip on Mondays and Wednesdays had one who did not take exam 2. Exam 2 is typically a more difficult exam in Statics as it includes much less prerequisite material. Exam 2 covers moments, rigid body equilibrium in 2- and 3-dimensions (including free-body diagrams), and friction. Exam 2 includes more questions where modeling a system is required. The grade comparison for Exam 2 across the sections is shown in Figure 4.

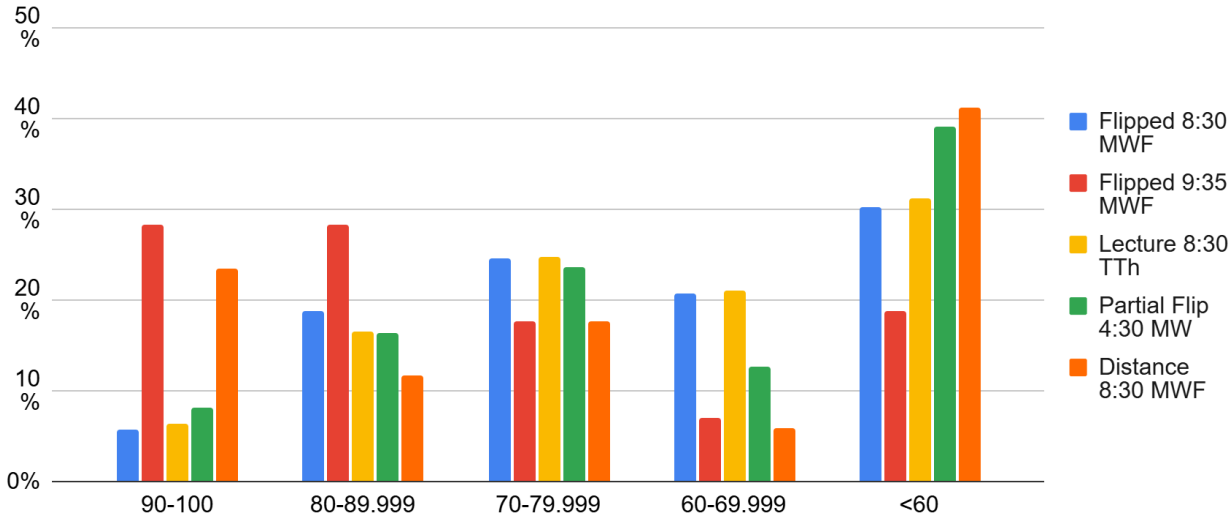



**Figure 4.** *Grade comparison for Midterm Exam 2*

The percentage of grades in the 90-100 and 80-90 ranges were considerably higher in the 9:35 MWF flipped class (red bar). The lowest percentage of A's on this exam came in the flipped 8:30 class (blue bar). Since the modality between the 8:30 and 9:30 MWF classes is identical, it's clear that the change in how the classes were offered is not the driving force for how the students perform.

Exam 3 takes place after the drop deadline for the class. As such, the number of students taking exam 3 is lower. Section 1: 103, Section 2: 82, Section 3: 109, Section 4: 110, and Distance: 17. The grade comparison for Exam 3 across the sections is shown in Figure 5.

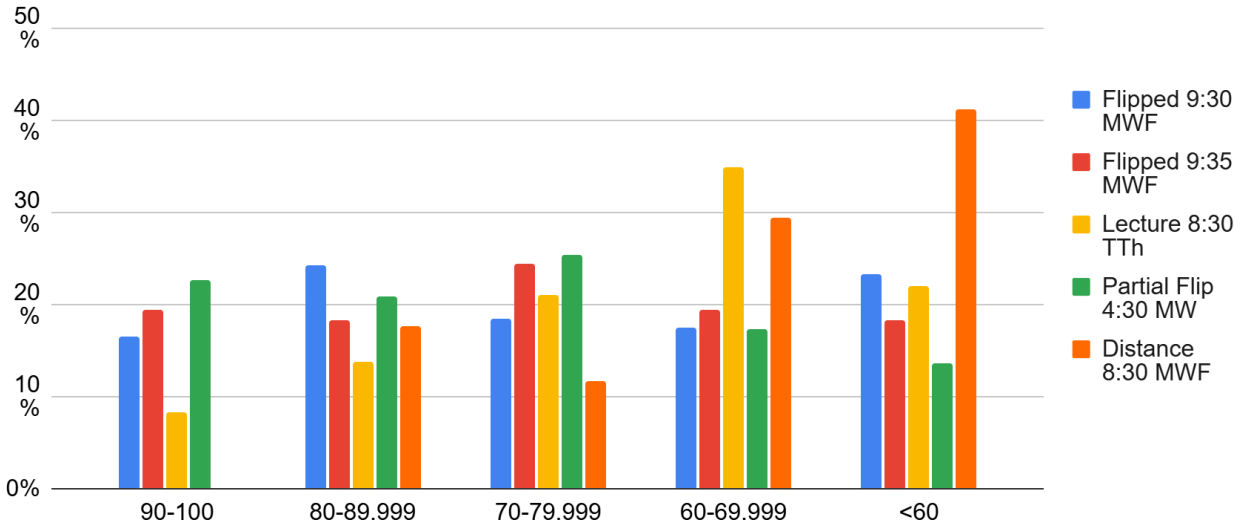



**Figure 5.** *Grade comparison for Midterm Exam 3*

The number of students taking the final exam were (respectively) 104, 81, 108, 108, and 17. These numbers were down 2, 4, 3, 3, and 0. Those drop-out rates were considered not statistically significant. The grade comparison for the Final Exam across the sections is shown in Figure 6.

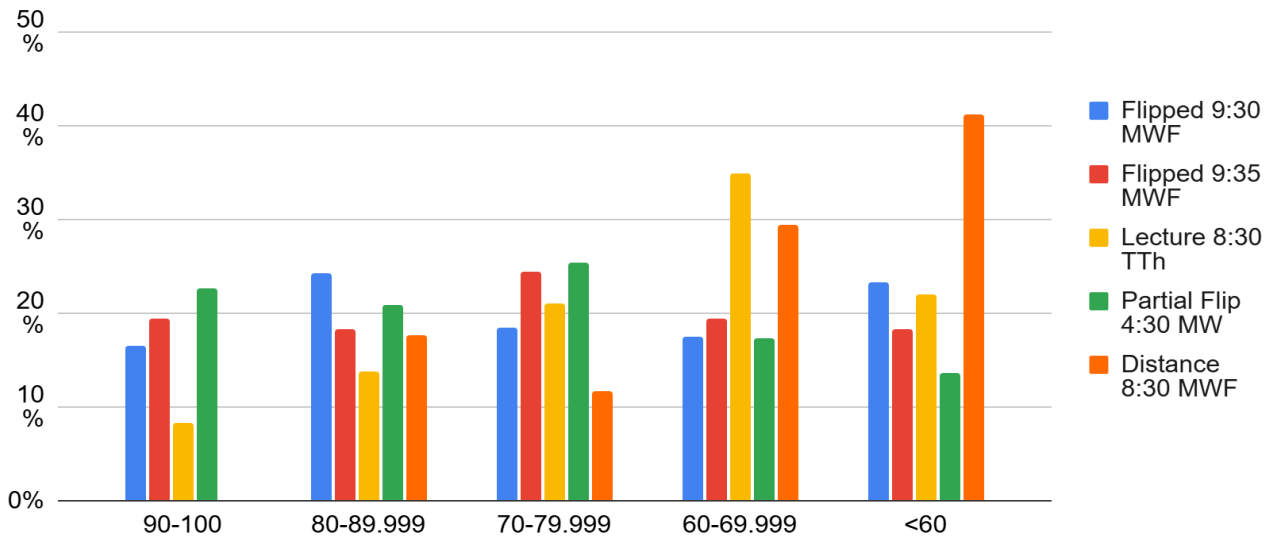



**Figure 6.** *Grade comparison for Final Exam*

There are no differences in the midterms or final exam scores which can be attributed to the teaching methods, since the methods for the blue and red bars (with the same professor and the same methods) show such a difference.

Comparing the grades on the weekly quizzes was more difficult. We can make some clear conclusions: week 8's quiz is easier than week 7's quiz as is shown in Figure 7.

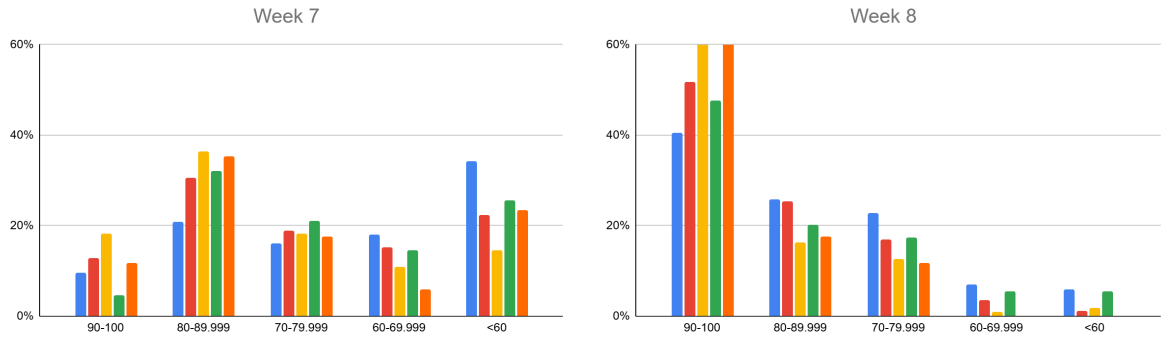



**Figure 7.** *Comparison of Sections for Week 7 and Week 8 Weekly Quizzes*

Figure 8 shows that the Week 3 and Week 6 Quizzes foreshadowed final exam grades, but again did not show a difference in the results from teaching modalities.

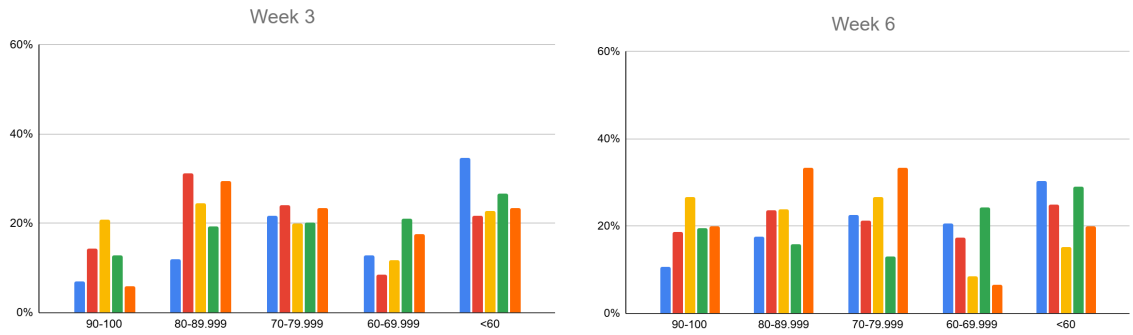
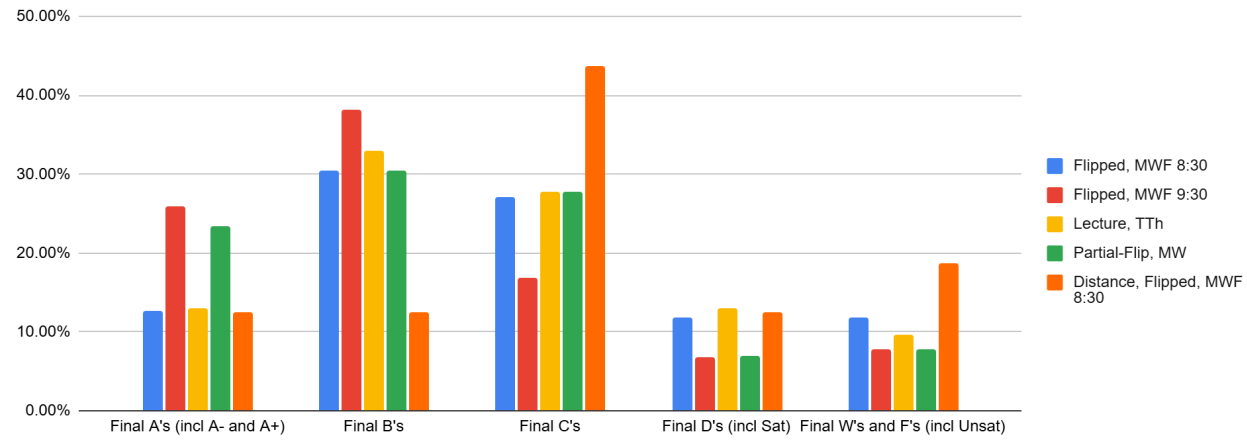



**Figure 8.** *Comparison of Sections for Week 3 and Week 6 Weekly Quizzes*

And last, we compared the overall class grades in the section. Note that these grades take into account the differences discussed in Table 1. We first looked at the number of students who dropped each section. Note that Statics is a C-wall course: students must score a C- or better to continue into Dynamics or Solids. The number of students who dropped out ranged between 3.5 and 6 for all the in-person sections with zero in the distance section. Again, this was not viewed as related to the modality of the offered instruction.

***Figure 9.*** *Final grade comparisons for different sections, passing grades*




The final grades in the 9:35 MWF class were better than the final grades in the 8:30 MWF class despite those being taught in the same way by the same instructor. The distance education class watched the in-person class 8:30 class and did almost as well as the students in-person. We were most interested in comparing the lecture (yellow bars) with the flipped classes (red and blue) and the partial flip (green). The differences between any two classes swamped the differences in modalities.

## Discussion and Conclusions

We had hoped that this work would help identify what aspects of the Statics curriculum are better suited for a flipped class vs a lecture class. After comparing the midterms and the final grades, we had a better understanding of the students in each class. Giving students the opportunity to choose their section with the better students going first likely allowed a greater number of our top students to avoid the 8:30 time slots (with three days a week getting up early being even worse than getting up early two days a week.)

The frustration of showing no statistically significant conclusions in a study such as this is mitigated by the clear indication that we three offered similarly strong classroom situations where a broad number of students could strive and succeed.

## References

[1] J. Hylton and L. Funke, “Journey towards competency-based grading for mechanical engineering computer applications,” presented at the 2022 ASEE Annual Conference & Exposition, Aug. 2022. Accessed: Jun. 20, 2023. [Online]. Available: https://peer.asee.org/journey-towards-competency-based-grading-for-mechanical-engineering-computer-applications

[2] A.K.T. Howard and A. D. Cole, “Weekly Quizzes in Lieu of Homework in Large Sections,” presented at the 2023 ASEE Annual Conference & Exposition, Jun. 2023. Accessed: Jan. 20, 2025. [Online]. Available: https://peer.asee.org/weekly-quizzes-in-lieu-of-homework-in-large-sections

[3] R. Averill, G. Recktenwald, and S. Roccabianca, “Effect of Assessment Methods on Performance in Mechanics of Materials,” presented at the 2018 ASEE Annual Conference & Exposition, Jun. 2018. Accessed: Feb. 20, 2023. [Online]. Available: https://peer.asee.org/effect-of-assessment-methods-on-performance-in-mechanics-of-materials

[4] A.K.T. Howard and N. Garcia, “Weekly Quizzes with No Homework,” presented at the ASEE Southeastern Section Conference, Mississippi State University, Starkville, MS. Jun. 2025.

[5] A.K.T. Howard, “Flipped Classroom – Ten Years Later,” presented at the 2019 ASEE Annual Conference & Exposition, Jun. 2019. Accessed: Jan. 20, 2025. [Online]. Available: https://peer.asee.org/flipped-classroom-ten-years-later

[6] G. Gaudette and S. Wodin-Schwartz, “Flying Forces: Adding Lift to Statics | Engineering Unleashed.” Accessed: Feb. 14, 2022. [Online]. Available: https://engineeringunleashed.com/card/2270

[7] S. Hargrove-Leak, “Static Sculpture,” Engineering Unleashed. Accessed: Jan. 20, 2025. [Online]. Available: https://engineeringunleashed.com/card/2379