Work-in-Progress: Understanding the Importance of Changes in Teaching Modality, Method, and Content on Student Success in an Introductory Aerospace Engineering Course

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Introduction

Pedagogical research regularly provides evidence supporting various improved methods of teaching students. Some common examples include the flipped-classroom model [1] – [4], reducing workload to focus on the essential skills and knowledge students need to learn and retain [5] – [7], avoiding early class times [8] – [11], and various forms of good teaching practices like active learning. For instructors, though, it can be overwhelming to wade through all the studies and determine the best approach for any given course.

Over the past decade, the Introduction to Aerospace Engineering course at The Ohio State University has been taught by various faculty, in a variety of modalities and using various methods, and including different content. The numerous changes in the course were driven by feedback from accreditors and students, as well as pedagogical literature and faculty availability. This inadvertently provides an opportunity to compare student performance in the course over the years and determine the relative impact of the various changes.

Course Information

Introduction to Aerospace Engineering is a second year course offered in autumn semester, and it is the first course in the major. It had an enrollment of 119-161 students for most of the period under consideration, with growth this year to 177. While the students are mostly aerospace engineering majors, the course is also taken as a technical elective by a few students in other majors (primarily Aviation and Engineering Physics). The course is laboratory-intensive, with ten labs spread across the 16 weeks. All students are in one lecture section (except for 2021 due to COVID restrictions forcing two lecture sections) but are split into lab sections of roughly 25 students.

The course has undergone changes in almost every aspect, rarely staying the same for two years in a row. The major structural changes are summarized in Table 1. The course has had three regular instructors over this period, with the most recent years taught jointly – Instructor #2 focused on the laboratory while Instructor #3 ran the lectures. The course began as a standard lecture course with three 55-minute lectures per week plus a weekly lab/recitation session taught by one instructor, with all content related to aeronautics. A second introductory course in the following spring semester contained some basic astronautics-related material that has been moved to the current introductory course. That second introductory course has since been replaced by a more focused astronautics course with the remaining material moved to the appropriate courses in the third year. One key change that happened due to COVID was moving the start time for the course back from 8:00am to 9:10am. It began in 2021 with one section at each time to keep safe social distance between students, then only the 9:10 time was retained once full room capacity was allowed again.

Table 1. Structural changes to the Introduction to Aerospace Engineering course

Year	Instructor(s)	Modality	Lectures	Lab/Recitation	Content
2015	#1	In-person lecture	M,W,F 55 minutes 8:00 am	M or F 110 minutes Various times	Aeronautics only
2016	#1	In-person lecture	M,W,F 55 minutes 8:00 am	M or F 110 minutes Various times	Aeronautics only
2017					
2018	#1 & #2	In-person, flipped	T,Th 55 minutes 8:00 am	M,W,F 55 minutes 8:00 am	Aeronautics only
2019	#1	In-person, flipped	T,Th 55 minutes 8:00 am	M,W,F 55 minutes 8:00 am	Aeronautics only
2020	#2	Synchronous online, flipped	T,Th 55 minutes 8:00 am	M,W,F 55 minutes 8:00 am	Aeronautics only
2021	#2	In-person, flipped	T,Th 55 minutes 8:00 or 9:10 am	M,W,F 55 minutes 8:00 or 9:10 am	Aeronautics & Astronautics
2022	#2	In-person, flipped	T,Th 55 minutes 9:10 am	M,W,F 55 minutes 9:10 am	Aeronautics & Astronautics
2023	#2 & #3	In-person lecture	T,Th 55 minutes 9:10 am	M,W,F 55 minutes 9:10 am	Aeronautics & Astronautics
2024	#2 & #3	In-person lecture	T,Th 55 minutes 9:10 am	M,W,F 55 minutes 9:10 am	Aeronautics & Astronautics
2025	#2 & #3	In-person lecture	M,W,F 55 minutes 9:10 am	T,Th 55 minutes 9:10 am	Aeronautics & Astronautics

In addition to structural changes, the number, types and lengths of the various exams have varied over the years as seen in Table 2. The final exam was cumulative in 2015-2020 since all the course content was aeronautics, and the same exam was used in each of those years. The cumulative final exam format was maintained in 2021, and about 2/3 of the final exam questions were retained (since some material was removed and astronautics content added, questions on the removed content were replaced with questions about astronautics). In all of these years, the first question was naming variables (in 2021 it was a mix of aeronautics and astronautics variables) with the other five questions being calculation problems. Three of the aeronautics questions and about 2/3 of the variables in Question #1 were retained for the 2021 final exam, with two new questions on astronautics. Anecdotal student feedback in 2021 was that trying to recall the aeronautics material after so many weeks of not using it was challenging and took considerably more study time than normal. Based on that, Instructor #2 switched in 2022 to treat the final exam as a midterm exam only covering astronautics content and reduced its length to three calculation problems so it would fit in the same 55 minute window as the other midterms. The students still had the entire 105 minutes to take the exam, but there was no chance for post-exam extra credit for fixing incorrect solutions as there was on the other midterms. This third midterm approach was continued in 2023-2025.

The other notable change seen in Table 2 is the number of midterm exams given each year. There were three 55-minute midterms plus a 105-minute cumulative final exam in 2015-2020. In 2021, the number of midterms increased to four to reduce the amount of material students needed to study for each exam and thus lower the stress.

Table 2. Summary of exam changes in the Introduction to Aerospace Engineering course

Year	Number of Midterms	Final Exam Type	Final Exam Designed Length (minutes)
2015	3	Cumulative	105
2016	3	Cumulative	105
2017			
2018	3	Cumulative	105
2019	3	Cumulative	105
2020	3	Cumulative	105
2021	4	Cumulative	105
2022	2	Astronautics Midterm	55
2023	2	Astronautics Midterm	55
2024	2	Astronautics Midterm	55
2025	2	Astronautics Midterm	55

As seen in Table 3, the weighting of each component of the course in terms of the overall grade also changed over time. In 2015-2016, midterms made up 40% of the final grade and the final exam 20%. After flipping the course, quizzes on the video lectures were added to the course and comprised 10% of the final grade. This was balanced by lowering the midterm weighting to 30%. The biggest set of changes happened in 2021 with the addition of astronautics material to the course. The advanced aeronautics material was removed to accommodate this addition, and this was the content for the final project so that was removed from the grading. In addition, the stakes for every exam and quiz were lowered in response to the stress students were under due to COVID. This increased the weighting for homework and lab reports significantly (from 25% combined to 40%). Those are the types of assignments students can work on as a group and thus not as reflective of the individual knowledge of each student, but it was suggested by the university to lower the stakes of all exams whenever possible. In 2022, Instructor #2 reduced the exam weighting a bit more as well as returning to two midterms with the final exam serving as a third midterm but increased the quiz weighting to make sure students watched the lecture videos based on analysis of viewership data from 2021. Instructor #3 maintained the weighting in 2023, but in 2024 shifted a little more weight onto the exams by reducing the homework weight. Each individual midterm also carried the same weight as the final exam. The weighting persisted for 2025.

2015-2016

The first two years (2015-2016) provide a baseline for student performance in the course, with two cohorts totaling almost 300 students. Instructor #1 taught the course with the aid of both graduate and undergraduate teaching assistants. There were three 55-minute lectures per week at 8:00 am with one 110-minute lab session (times varied). The course content focused on thermodynamics, aerodynamics, and aircraft performance. The instructor felt that student performance was not as strong as it could be and sought to make significant changes to the course in the future (XXX, personal communication, October 2018). He took several months off in 2017 to record high-quality lecture videos using a lightboard and some guidance from a professional video editor. The videos were kept short (average length was about seven minutes) in accordance with best practices. Another instructor taught the course that year while Instructor #1 was recording the videos, so no results from that year will be shared.

Table 3. Weighting of course components (in %) in the Introduction to Aerospace Engineering course by year

Year	Midterms	Final Exam	Homework	Labs	Quizzes	Participation	Final Project
2015	40	20	13	12	-	5	10
2016	40	20	13	12	-	5	10
2017							
2018	30	20	13	12	10	5	10
2019	30	20	13	12	10	5	10
2020	30	20	13	12	10	5	10
2021	35	15	20	20	5	5	-
2022	25	10	25	20	15	5	-
2023	25	10	25	20	15	5	-
2024	26.67	13.33	20	20	15	5	-
2025	26.67	13.33	20	20	15	5	-

2018-2019

Instructor #1 returned to teaching the course in 2018. Because he was using the flipped-classroom model, the course delivery structure was changed. The course shifted to two 55-minute lectures per week at 8:00 am, with the time spent on a review of the material and then working example problems. The lab was broken into three 55-minute sessions per week at 8:00 am so that students had to think about the material five days per week. All the lab experiments in the course were quite short so the multiple teams could rotate through sharing equipment as needed (like wind tunnels), so there was still sufficient time to run the lab during one of the three sessions. The other two sessions were used for recitation. Instructor #2 helped develop a new lab experiment in 2018 and gave some lectures but primarily helped on the administrative side while learning about the course. In 2019 Instructor #2 had less student-facing involvement, giving only a couple of lectures while helping administratively. The same final exam was used from 2015-2019 so that Instructor #1 could judge the impact of the course change on the students.

2020-2022

In 2020, Instructor #2 took over as the course instructor. The course material remained the same, but due to COVID-19 the lectures were held synchronously online while the labs were performed with fewer students in the room at one time and all of them standing six feet apart while trying to work together. Due to the reduced capacity of the lab room, labs had to be stretched out over multiple weeks with some students performing the lab well before the lectures got to the material. A synchronous online lecture at 8:00 am was not well received by students that year, and the student performance was reduced. In addition, it should be noted that out of state students were only charged in-state tuition if all of their courses were online. Because of the labs in this course, all out of state students had to pay the full out of state rate which made the course unpopular. The same final exam was used in 2020 as in previous years to judge the effect of changing instructors.

In 2021 the lectures returned to in-person but were socially distanced and with a reduced room capacity. That required two sections, one at 8:00 am and the other at 9:10 am. The labs remained socially distanced but with full room capacity so they ran on the normal schedule. The bigger change was to the course material. To increase the amount of space-related content in the curriculum, significant changes were made to the content in this course. The final five weeks of the course were devoted to orbital mechanics and rocket propulsion, replacing most of the content on aircraft performance. In addition, some of the aeronautics content was removed to reduce the bottlenecks the students typically ran into with certain concepts by giving them more time to absorb the material. The addition of space-related content required making new videos, but these could not be of the same quality due to facility restrictions. However, they did feature Instructor #2. To reduce the stakes of the exams for students already under stress due to the pandemic, the course switched from two midterms to four equally spaced throughout the semester. The addition of space-related material as well as removal of some aeronautics content also required changes in the final exam, but some problems were re-used.

In 2022, social distancing was no longer required so the course returned to one large lecture section. The time was moved to 9:10 am based on student feedback, instructor feedback, and student performance. The material in the course was slightly adjusted from the previous year. The bigger change was to the lecture videos themselves. The previous cohort of students complained that most of the lecture videos featured an instructor they did not know, so the high-quality lecture videos were replaced with new ones of inferior quality by Instructor #2. The students then complained about the quality of the new videos. The final exam was changed to be a midterm over most of the space-related content rather than a cumulative exam based on the difficulties students had the previous year in retaining the aeronautics content, but this did re-use some of the questions from the previous year.

2023-2025

To better balance the workload among the faculty, in 2023 the department decided to have the introductory course be co-taught. Instructor #3 gave all the lectures while Instructor #2 ran the labs. Both worked administratively, managing the teaching assistants, office hours, and student emails. Instructor #3 was not comfortable with the flipped-classroom model and chose to return to a traditional lecture format. There were still only two 55-minute lectures per week, though, which required some compromises in terms of pacing or skipping material. But the course maintained its five days per week structure as well as keeping the same weekly quizzes, although now the quizzes come the week after the material was taught instead of before the flipped class worked on it. The final exam remained the same as the previous year.

Now feeling comfortable with the course, Instructor #3 made some changes in 2024. He removed some of the content he could not cover the previous year and also shortened many of the assignments by removing problems from homework sets or reducing the work needed for certain lab reports. He also streamlined the exams by removing parts of individual problems or eliminating some of the work by providing the information instead. Another change came in reducing the role of the teaching assistants. They no longer performed most recitation duties, instead supervising students working on assignments when they were not actively running a lab. Only the two graduate teaching assistants held office hours, not the five undergraduates. The final exam was a streamlined version of the previous year's exam.

Similar changes in the same vein were made by Instructor #3 in 2025. A little more material was removed and a few more assignments were shortened to reduce the workload on students. Moreover, the number of lectures was increased from two to three per week to give more time for problem solving in class. As a result, recitation time was reduced from three to two sessions and TA workload also reduced. A different method of giving partial credit was used when grading exams as well.

Results

There are many ways to assess student performance. The available data that covers this entire period is limited, however, so the focus will be on the final course grades for each cohort of students. While only one aspect of student performance, it gives a quick way to see the impact of various changes to the course. A secondary result is the average final exam score for each cohort. That can be used to compare the impact of certain changes, but not all of them as the final exam did not stay the same the entire time.

Course Grades

Figure 1 shows the average course grade for each cohort over the time under discussion. The first notable feature is that the averages neatly separate into three groups: the years before the flip (2015-2016), the years after the flip with a cumulative final exam (2018-2021), and the years with a non-cumulative final exam (2022-2025). Each group is marked with a different color and point style, with dotted lines added to indicate the average value for the group. The large jump from the means for 2015-2016 (average = 70.3) to the flipped-classroom model years of 2018-2021 (average = 81.6) supports the flipped-classroom approach to teaching, as seen in the literature. The jump from 2018-2021 means (average = 81.6) to the non-cumulative final exam years 2022-2025 (average = 91.2) shows that the move to a non-cumulative final exam in 2022 also had a significant impact. The lack of notable impact from unflipping the course in 2023 should be noted as well.

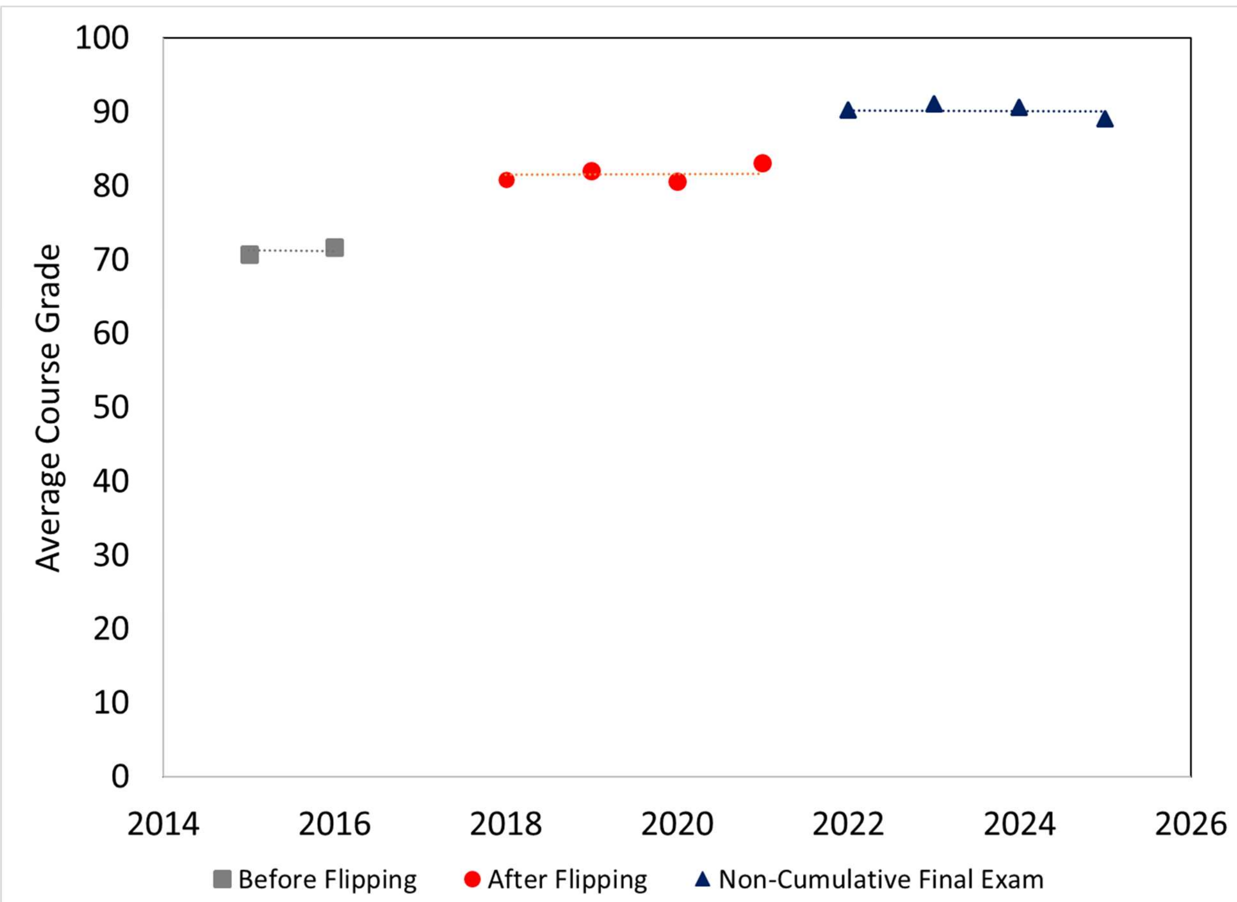

Figure 1. Average course grades for each student cohort by year. The values are grouped by similar years with the commonality noted (2015-2016 – Before Flipping, 2018-2021 – After Flipping, 2022-2025 – Non-Cumulative Final Exam). The dotted lines indicate the average value for each group of years.

Table 4 provides the mean, median and standard deviations for each cohort along with the number of students in each cohort. The data show that not only are the mean values consistent within each group, so are the medians and standard deviations. This is examined further in Table 5, where the average values for the mean, median, and standard deviation for each group of years are shown along with the average number of students. Having seen this grouping of years by major changes in the course structure and assessment methods, it was decided to analyze the course grade distributions in greater depth.

Table 4. Mean, median, and standard deviation values for overall course grades in the Introduction to Aerospace Engineering course by year

Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Students	149	161		121	139	156	145	119	156	146	177
Mean	70.8	71.7		80.9	82.0	80.5	83.1	90.2	91.0	90.5	89.0
Median	71.6	73.3		83.1	83.9	81.8	84.3	92.2	92.3	92.0	90.9
Standard Deviation	11.0	12.8		10.4	9.26	9.69	9.03	7.33	5.87	6.69	9.27

Table 5. Averaged values over 2015-2016 (before flipping), 2018-2021 (cumulative final exam), and 2022-2025 (non-cumulative final exam) for the mean, median, and standard deviation values for overall course grades in the Introduction to Aerospace Engineering course by groups of years

Year	**2015 - 2016**	**2018 - 2021**	**2022 - 2025**
Average # of Students	155	140.25	149.5
Mean	71.3	81.6	90.2
Median	72.4	83.3	91.8
Standard Deviation	11.9	9.59	7.29

Course Grade Distribution

Figure 2 shows the distribution of course grades for each cohort over the time under discussion. The first notable feature is how cleanly the distributions align within each group of years: the years before the flip (2015-2016), the years after the flip with a cumulative final exam (2018-2021), and the years with a non-cumulative final exam (2022-2025). This matches what the mean score data showed, and more importantly shows that the grade improvement applies across all percentiles. The large jump from the distributions for 2015-2016 to the flipped-classroom model years of 2018-2021 supports the flipped-classroom approach to teaching since all students showed notable improvement.

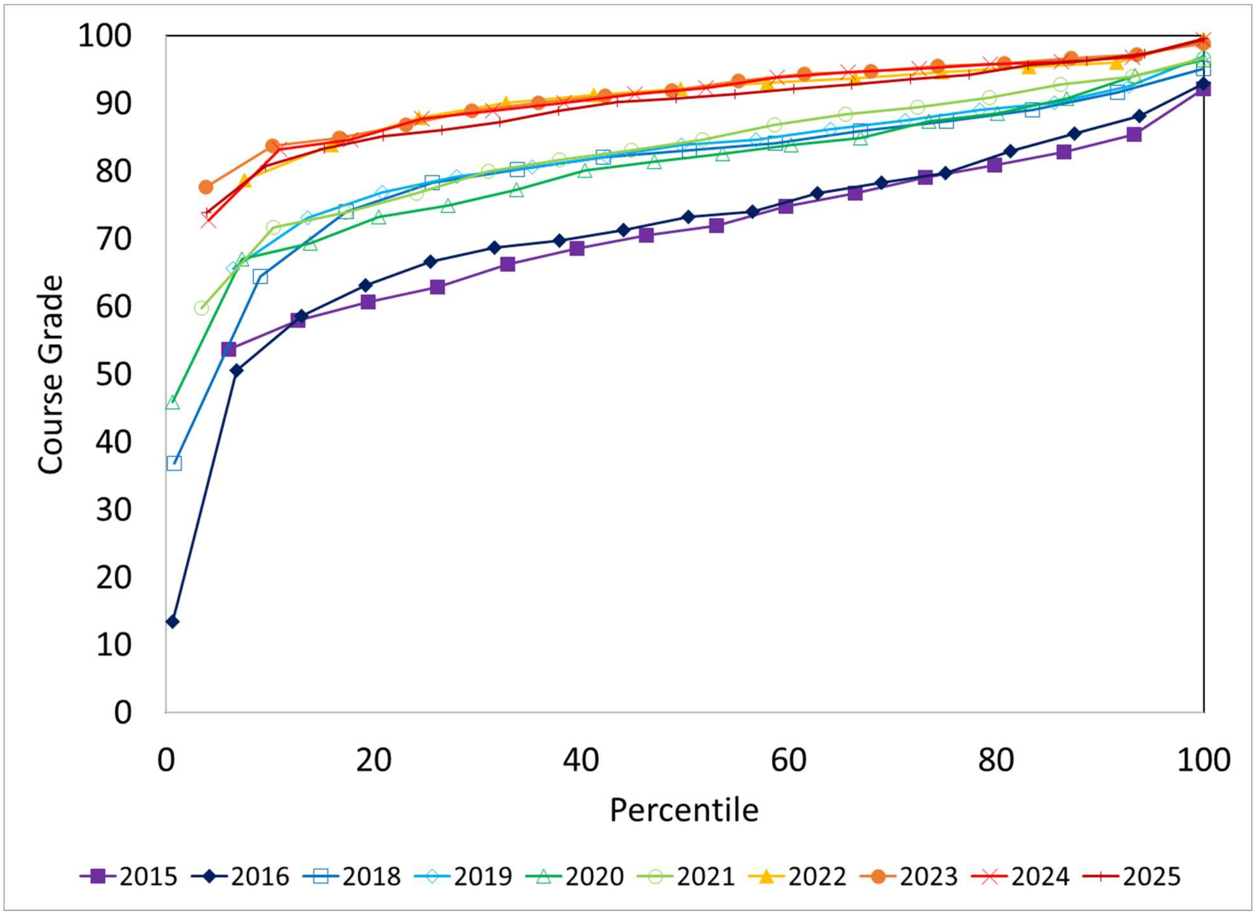

Figure 2. Final course grade distributions for each student cohort by year. The distributions are shown by percentile due to differing cohort sizes.

The relative consistency of the distributions for 2015-2016 gives an idea of the natural variation between cohorts. The similarity of the distributions for 2018-2021 indicates that all the course changes between those years had only minor impacts on the grades students earned. That does not guarantee equal learning, especially during the pandemic years, but it is interesting how little the grades changed. The same is true for the grades since switching to the non-cumulative final exam.

One feature to analyze was how consistent the improvement was within each cohort. The first step was to quantify the student performance. Because the cohort size varied each year, the course grades were sorted and percentiles determined. Table 6 shows the course grades at every tenth percentile (10^{th}, 20^{th}, …).

Table 6. Overall course grades at each percentile rank in the Introduction to Aerospace Engineering course by year

Percentile	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
99th	92.1	92.9		95.1	97.0	96.4	96.6	99.6	98.9	99.4	99.6
90th	84.4	86.5		90.5	92.0	92.3	93.2	96.0	96.9	96.6	96.6
80th	80.9	82.2		88.0	89.0	88.6	91.5	95.3	95.8	95.8	94.9
70th	78.4	78.4		87.0	87.4	85.7	89.4	94.3	95.2	94.9	93.3
60th	75.2	75.4		84.7	85.4	83.9	87.2	93.2	94.3	94.1	92.1
50th	71.6	73.3		83.1	83.9	81.8	84.3	92.2	92.2	92.0	90.9
40th	69.3	70.7		80.9	81.9	80.1	82.4	91.1	90.8	90.4	89.2
30th	65.3	68.2		79.2	79.6	76.2	79.5	89.4	89.0	88.8	87.0
20th	60.8	64.5		76.0	76.8	73.2	75.1	86.9	86.4	85.5	85.0
10th	56.6	57.4		68.2	68.7	68.3	71.7	80.7	83.7	82.5	81.1

Based on the relative consistency of the distributions for each group of years as seen in Figure 6, the values within each group of years were averaged for each of the tabulated percentile ranks (10th, 20th, …). Then the differences between the year groups was calculated to determine how much the gap to a grade of 100 closed after each major change. This data is shown in Table 7.

Table 7. Averaged overall course grades at each percentile rank in the Introduction to Aerospace Engineering course by year groups

Percentile	2015 - 2016	2018 - 2021	Change	% Gap Decrease	2022 - 2025	Change (vs 2018 - 2021)	% Gap Decrease	Change (vs 2015 - 2016)	% Gap Decrease
99th	92.5	96.3	+3.8	50.5	99.4	+3.1	82.5	+6.9	91.3
90th	85.4	92.0	+6.6	45.3	96.5	+4.5	56.6	+11.1	76.3
80th	81.5	89.3	+7.7	41.8	95.5	+6.2	57.7	+13.9	75.4
70th	78.4	87.4	+9.0	41.6	94.4	+7.0	55.6	+16.0	74.0
60th	75.3	85.3	+10.0	40.5	93.4	+8.1	55.3	+18.2	73.4
50th	72.4	83.3	+10.8	39.4	91.8	+8.5	51.1	+19.4	70.3
40th	70.0	81.3	+11.3	37.7	90.4	+9.1	48.6	+20.4	67.9
30th	66.8	78.6	+11.8	35.6	88.6	+10.0	46.5	+21.8	65.6
20th	62.6	75.3	+12.6	33.8	85.9	+10.7	43.1	+23.3	62.3
10th	57.0	69.2	+12.2	28.4	82.0	+12.8	41.6	+25.0	58.2
Average			+9.6	39.5		+8.0	53.9	+17.6	71.5

Flipping the course in 2018 led to a consistent improvement of roughly +10 points in the overall grade, or one full letter grade improvement. The top students did not benefit as much since they had less room for improvement, but that means the struggling students benefited even more. When viewed as a percentage gap decrease of the original gap from the score for that percentile student to a 100, it was consistently around 40% for the 40-80 percentile ranks. The students at higher percentile ranks had less room for absolute improvement, but as a percentage they improved even more. The lower-percentile students were still showing gains around 30%.

On top of those gains, the move to a non-cumulative final exam in 2022 stimulated another significant improvement in overall grades. This time the absolute improvement was more like +8 points in the average overall grade, but the gap reduction was closer to 50% for most students. Looking at both sets of improvement combined, students saw an average of +18 points in overall grade from 2015-2016 to 2022-2025 with the gap to a 100 reducing by 71%. That is a tremendous improvement, but the magnitude of the impact of changing the final exam was noted as deserving further investigation to see if that was truly the cause.

Final Exam Grades

The first way to look at final exam scores is to track the mean and median scores for each cohort, along with the standard deviation as seen in Table 8.

Table 8. Mean, median, and standard deviation values for final exam grades in the Introduction to Aerospace Engineering course by year

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Students	149	161		121	139	156	145	119	156	146	177
Mean	64.6	59.2		75.4	78.1	64.8	72.9	90.7	91.7	87.1	84.8
Median	65.0	61.0		79.0	80.0	65.0	73.0	93.5	95.0	90.5	90.0
Standard Deviation	16.4	17.4		16.4	14.6	16.9	15.2	11.3	11.8	14.8	17.2

The impact of COVID is seen in the lower 2020 score, but otherwise these scores show similar consistency within the same year groups as the overall grades. The average values for each of the year groups are shown in Table 9.

The pre-flipping average was a 61.9, with a jump of +10.9 points to 72.8 in the four years after flipping the classroom. Without the lower score in 2020 due to COVID, the post-flipping average would be 75.5 (+13.6). Switching to a non-cumulative final exam for the final four years led to a jump of +15.8 points to 88.6. The mean values for each year are shown in Figure 3, with the dotted lines representing the average value for that group of years.

Table 9. Averaged values over 2015-2016 (before flipping), 2018-2021 (after flipping), and 2022-2025 (non-cumulative final exam) for the mean, median, and standard deviation values final exam grades in the Introduction to Aerospace Engineering course by groups of years

Years	**2015 - 2016**	**2018 - 2021**	**2022 - 2025**
Average # of Students	155	140.25	149.5
Mean	61.9	72.8	88.6
Median	63.0	74.3	92.3
Standard Deviation	16.9	15.8	13.8

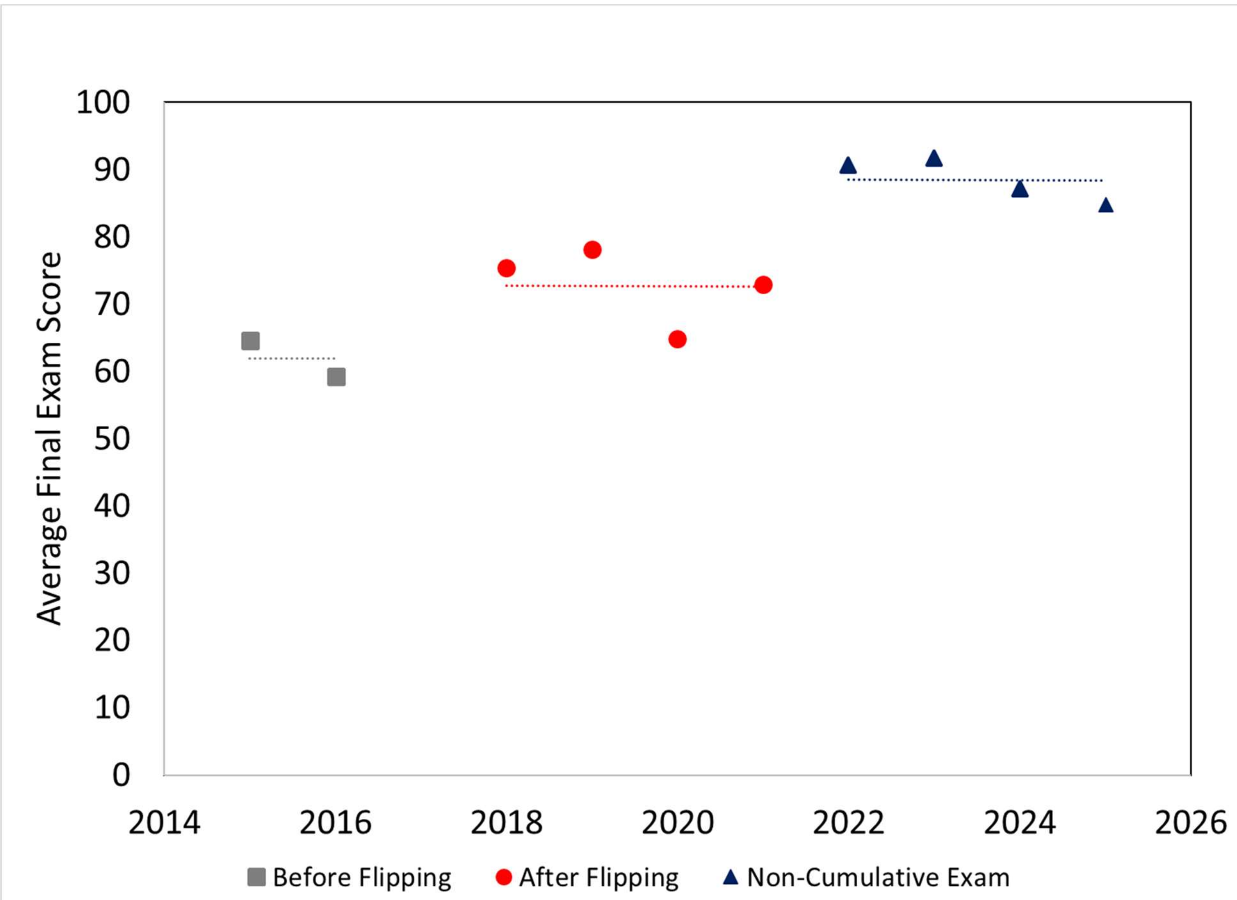

Figure 3. Average final exam grades for each student cohort by year, with dotted lines marking the average value for the group of years.

Earlier it was noted that the exact same final exam was used in 2015-2020. This provides a basis for direct comparison of the impact of flipping the course (2015-2016 vs 2018-2019) as well as the effects of a pandemic plus changing the main instructor (2018-2019 vs 2020). The flipping of the course resulted in a +14.8 points improvement in mean final exam score when comparing the groups of two years before and after the flip (61.9 to 76.7). The 2020 data shows a -11.9 point impact (76.7 to 64.8), but there is no good way to separate the effects of a pandemic and the changes it forced (virtual lecture classes, etc.) from changing the main instructor.

The final exam started changing after that, so less can be extracted from the numbers. However, problems #2, #3 and #4 were used again in 2021. The final exam scores rebounded by +8.1 points in 2021 as COVID impacts lessened and Instructor #2 had more familiarity with the course. Or perhaps it was the course change to include astronautics material. This is examined in Table 10, which looks at the mean score by percentage on the questions carried over from previous years versus the mean overall score.

Table 10. Mean score values on the 2021 final exam for Questions #2-4, which were recycled from previous years, and overall.

Mean Score Type	Score (%)
Questions #2-4	71.2
Overall	72.9

The mean scores were quite similar, 71.2% for the recycled questions vs 73.2% overall. Considering that the overall score also includes a simple variable-naming question that was partially recycled from the previous exam, the performance on calculation problems was similar on both types of material. And since the aeronautics material removed from the prior exam was the more difficult material, it is reasonable to say that the performance on Questions #2-4 in 2021 was similar to that in 2018-2019. Further investigation into problem-by-problem scoring would be required for a rigorous comparison, but this correlates with the overall scores that showed 2021 performance to be similar to 2018-2019.

Returning to the mean final exam scores by cohort (Table 8), the next notable change is the significant improvement in 2022 and subsequent years. 2022 is when the final exam changed to being the same length as a midterm despite students still having the 105 minute time block to take it, and not being cumulative – it solely covered astronautics. It is also when the course moved to only having lectures at 9:10 am instead of 8:00 am. Anecdotally Instructor #2 noted that the students had more energy in the later section in 2021 and that drove the selection of the later start time. The average mean final exam score for 2022-2025 was 88.6, a +15.8 point change from the average in 2018-2021. All of the above factors contributed somewhat to that increase, and there is no way to parse their impacts. It makes sense that only testing on the most recent material would improve student performance, as would having fewer problems to solve in the same amount of time.

This improving final exam performance leads to consideration of the way overall grades are calculated. After all, final exams are at most 20% of the overall grade so even a large improvement in the final exam score should only have a minor impact on the overall grade.

Course Component Weights

The weights given to each type of assignment when calculating the overall grades in the course were shown in Table 3. Over time exams have decreased in weight while homework assignments and lab reports have increased in weight. To see the impacts of this, each year's weighting formula was applied to the individual assignment scores from 2025 to calculate overall grades. For years without quizzes (before the flip), the quiz component had 0 weight. For years with a final project it carried 10% of the overall grade, so only the other components were included to calculate the other 90% of the grade and are shown in Table 11 as the percentage of a score of 90 they represent.

Despite the significant changes in weighting over the years, with roughly factor of two changes in the weight of final exams, midterms, homework, and lab reports, the result is consistent with a high of 89.0 and a low of 86.4. This shows that the changes in student performance drove the significant increases in overall grades both when the course was flipped and again when the final exam became non-cumulative.

Table 11. Calculated overall mean grades using 2025 student performance with the component weights for each year as shown in Table 3.

Year	Calculated Grade
2015	86.8
2016	86.8
2017	
2018	87.6
2019	87.6
2020	87.6
2021	88.2
2022	89.4
2023	89.4
2024	89.0
2025	89.0

Conclusions

Collectively the results indicate that many things can impact student performance, but not all changes are important. Flipping the course in 2018 had a tremendous impact on the grades, helping all students significantly. Moving to a non-cumulative final exam in 2022 also helped everyone a large amount. That change was combined with moving the class time from 8:00 am to 9:10 am which may also have helped the students. Conversely, the evidence shows that changes in the weighting of different course components did not have a significant effect on the student performance overall. Neither did a major change in course content, or the number of midterms.

The most surprising result was that unflipping the course in 2023 did not lower the overall student grades. However, unflipping was combined with Instructor #3 beginning to co-teach the course. Instructor #3 felt rushed in covering the material and thus did not cover all the material that was covered previously, so the reduction in content for the students may have contributed to their continued high performance. Instructor #3 may have shown more flexibility in dealing with student issues (late/missing assignments, etc.) despite having the same syllabus policies as Instructor #2 or held office hours that were more helpful to the students. His arrival also reduced the workload on the individual instructors, which may have improved overall instructor performance. It is possible that these changes compensated for the switch back to a traditional lecture format. Further analysis is necessary to isolate the cause and effect in this situation. It may be that flipping the course introduced a package of course changes and that much of the benefit for students came from these other changes, not the actual flipping itself.

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