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Hiring instructional faculty improves student achievement in large foundational engineering mechanics courses.

James Lord (Collegiate Assistant Professor)

James earned a Ph.D. in Biomechanical Engineering from Newcastle University, England in 2012 for his work on metal-on-metal hip prostheses. He works as a collegiate assistant professor in the Department of Biomedical Engineering and Mechanics at Virginia Tech, where he coordinates and teaches introductory courses in statics and mechanics of materials. Research interests include pedagogy and policy for large introductory mechanics classes, assessment measures of both students and faculty, and the effects on student learning of increased reliance on teaching-faculty without tenure.

Hiring instructional faculty improves student achievement in large foundational engineering mechanics courses.

Abstract

Over the past several decades, faculty demographics at US institutions have shifted from a majority of instructional faculty being in tenure lines in the 1970's to now a majority being non-tenure-track (NTT). There are concerns about the effect this shift has on the quality of education students receive.

Teaching large foundational engineering courses presents a challenge for departments and faculty. Faculty may be required to teach multiple sections of the course, each with large numbers of students. Properly teaching this many students each semester takes a significant time commitment, which can be difficult for tenured/tenure-track faculty to carve out amongst research, service, and advising obligations. Tenured/tenure-track (T/TT) faculty teaching these courses must carefully balance their time between students and their other obligations, while NTT instructional faculty are able to spend more time with each student and thereby potentially improve student outcomes.

We analyze student grade data and withdrawal rate for large multi-section foundational engineering mechanics courses when those courses are taught by full-time NTT instructional faculty and compare the results to when those classes are taught by tenured/tenure-track faculty. We reviewed 15 years of grade and enrollment data for three large multi-section foundational engineering mechanics courses at our institution, with each section taught by either a T/TT faculty member or a full-time NTT instructional faculty member. We analyzed data on class size, average grade and the proportion of students receiving either D grades, F grades, or withdrawing from the course (collectively known as DFW rate), and compared these between the two faculty groups.

We find that class sections taught by full-time NTT faculty typically result in higher GPAs and lower DFW rates. Although class sizes were typically smaller for this group, these relationships held when we separated our data and compared class sections of similar size. We show a mild trend that larger class sizes correlate with lower GPAs and higher DFW rates

We suggest that NTT faculty can have a positive effect on student education, provided those faculty are well supported by their institution.

Background

Over the past several decades, faculty demographics at US institutions have shifted from a majority of faculty being in the tenure system in the 1970s to only 27% in 2016 [1]. At R1 institutions, approximately 30% of instructional faculty are in the tenure system, while 27% are

full-time non-tenure-track (NTT) and 14% part-time. Two-year colleges and community colleges tend to skew to fewer faculty in the tenure system and more part-time faculty.

While there are benefits in reduced costs and increased enrollment capacities, some studies suggest that increased NTT appointments are associated with poorer student outcomes. It has been noted that students tend to achieve higher grades in courses taught by NTT faculty [2] but lower grades in subsequent courses [3], indicating that students are not getting the same deep learning from these courses. Additionally, while failure rates are often lower in courses taught by NTT faculty, students may be less likely to take another course in the same field of study if their first exposure to the field was not with full-time faculty [3-5] thereby reducing overall retention.

However, these studies typically focus on part-time NTT faculty. These faculty are often unable to devote additional time to students outside of the classroom [6, 7], may spend less time preparing for class [8], may have less teaching experience [9], and are less likely to hold advanced degrees [3]. In short, part-time faculty often have necessary commitments outside of their part-time teaching.

Full time NTT faculty on the other hand, are likely to be able to spend more time with students outside the classroom than either their part time NTT or full time tenure-track colleagues, have more time available to dedicate to teaching and pedagogy, and generally receive better institutional support than their part-time colleagues [10, 11]. Under these conditions, studies have shown that NTT faculty can have a positive effect on students [12]. Even part-time faculty can provide accessibility and course related support on par with tenured/tenure-track (T/TT) faculty if they receive appropriate institutional support [11].

A study of first-year students at Northwestern University found that students learn relatively more from NTT professors in their introductory courses than from T/TT faculty, were more likely to take more classes in the same field of study, and were more likely to do better in subsequent coursework [13]. The NTT faculty in this study generally had a long-term relationship with the university, were well-paid contracted lecturers, did not have to split time between research and teaching (as T/TT faculty typically do), and did not face many of the concerns and lack of support that part-time NTT faculty often do [14].

This is an important distinction. As the number of full-time NTT faculty continues to increase, the effects of this group on student achievement are of increasing interest. If increased institutional support (such as full-time positions, longer contracts, permanent office spaces, etc.) results in NTT faculty whose students achieve similar or better outcomes than T/TT faculty in certain courses, this may inform policy, hiring practices, and teaching assignments.

Teaching large foundational engineering courses presents a challenge for departments and faculty, especially when these courses are taken by students across multiple departments. Faculty may be required to teach multiple sections of the course, each with large numbers of students. Properly teaching this many students each semester takes a significant time commitment, which

can be difficult for tenured/tenure-track faculty to carve out amongst research, service, and advising obligations. T/TT faculty teaching these courses must carefully balance their time between students and their other obligations, while full-time NTT faculty are able to focus more on teaching, spend more time with each student and thereby potentially improve student outcomes. Full-time NTT faculty can also typically teach more class sections per semester than either part-time NTT or full-time T/TT faculty, thereby allowing either more students to enroll in these classes each semester or (if the total number of students remains roughly the same) allowing for reduced section sizes. Smaller class sections are typically associated with improved student outcomes [15, 16].

In this initial study we investigate whether there are significant differences in student outcomes for foundational mechanics courses at our R1 institution when those courses are taught by full-time NTT instructional faculty compared with full-time T/TT faculty. This study focuses only on the results within a specific course, and will inform future studies examining the effects on subsequent courses. Specifically, we compare grades achieved by students when a course is taught by full-time NTT faculty or by full-time T/TT faculty. We also investigate if there is a difference in failure and withdrawal rates for students in these courses.

Methods

We selected courses for inclusion in this study based on the following criteria: (i) the course covers foundational mechanics content at an undergraduate level, (ii) multiple sections of the course are taught each semester, (iii) section sizes are medium-to-large (typically 50-150+ students per section), and (iv) the course has a history of being taught by both tenured/tenure-track faculty and instructors. Three courses were identified: ESM 2104 Statics, ESM 2204 Mechanics of Deformable Bodies (MDB), and ESM 2304 Dynamics.

Each of these courses has a course supervisor that sets the course schedule and ensures consistency in content both across sections in a given semester and across semesters. The final exam for each course is common to all sections each semester, and each course section assigns grades according to the same breakdown (15% homework, 60% midterm exams, 25% final exam). Each faculty member creates their own midterm exams and homework assignments. The NTT instructional faculty included in this study all hold full-time appointments and multi-year contracts. They generally have a long-term relationship with our institution, and their primary focus is teaching. Research is not an expectation (though some choose to conduct research in their spare time) and service obligations are minimal.

We reviewed enrollment and grade data for all sections of these courses taught over a 15 year period between Fall 2006 to Spring 2021 (30 semesters). During this time, there were 154 sections of Statics, 150 sections of MDB, and 126 sections of Dynamics. We identified whether the instructor of record for each section was employed as tenured/tenure-track faculty or as instructional faculty. A breakdown is shown in Table 1. We excluded 2 sections of MDB that were taught by graduate students from further inclusion in the study.

Course	Number of sections	
	Tenured/tenure-track	Instructor
Statics	60	94
MDB	68	80
Dynamics	43	83

Table 1: Number of section of each course taught by tenured/tenure track faculty and instructional faculty

For each section, we first determined the Grade Point Average (GPA) and the proportion of students receiving either D grades, F grades, or withdrawing from the course (collectively known as DFW rate). For each of the 30 semesters, we averaged this data for each faculty group and plotted the results to see if there were significant shifts over time.

For each course, we then calculated the mean GPA and mean DFW rate for each faculty group and compared these values. We conducted single-factor ANOVA tests to test for significance. To determine if class size had an effect on these values we calculated the correlation coefficient between enrollment and GPA, and between enrollment and DFW rate, for each course and each faculty type. We compared class sizes for the two faculty groups.

To mitigate the effect of class size on the data, we then separated our data into groups based on enrollment, with cut-offs every 50 students. This data is shown in table 2. We selected groups for further analysis if there were at least 5 sections of that class size taught by both full-time NTT faculty and T/TT faculty. For Statics we selected class sizes of 51 – 100 and 101 – 150. For Mechanics of Deformable Bodies we selected class sizes of 1 – 50, 51 – 100, and 101 – 150. For Dynamics we selected class sizes of 1 – 50 and 51 – 100.

Class enrollment	Number of sections					
	Statics		MDB		Dynamics	
	Inst.	T/TT	Inst.	T/TT	Inst.	T/TT
1 – 50	13	2	20	18	28	8
51 – 100	59	22	53	28	51	26
101 – 150	20	9	5	16	3	3
151 – 200	1	2	1	6	0	5
>200	1	25	1	0	1	1

Table 2: Number of sections of each course taught by tenured/tenure-track faculty and instructional faculty, separated by section enrollment

For these groups we again calculated the correlation coefficient between enrollment and GPA, and between enrollment and DFW rate, and compared these results between the two faculty groups. Finally, we compared GPA and DFW rate for tenured/tenure-track faculty and instructional faculty in classes of similar enrollment. We conducted single-factor ANOVA tests to test for significance in these comparisons.

Results

Figure 1 shows the GPA for each Statics course section across the 30 semesters, separated by faculty group. Figure 2 shows the DFW rate for each Statics course section across the 30 semesters, again separated by faculty group. Figures 3 and 4 show similar plots for Mechanics of Deformable Bodies, and figures 5 and 6 show similar plots for Dynamics. While there is natural variability in these measures, there are no obvious patterns or shifts over time.

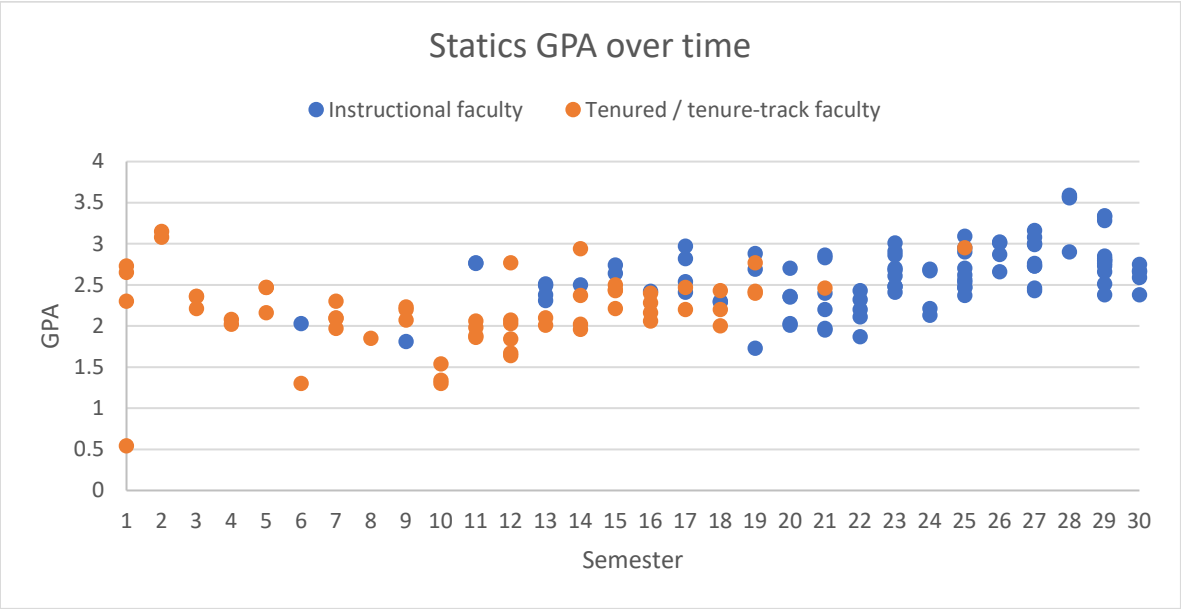

Figure 1: Statics GPA in each semester (Fall 2006 to Spring 2021), separated by faculty group. Each dot represents one section of the course.

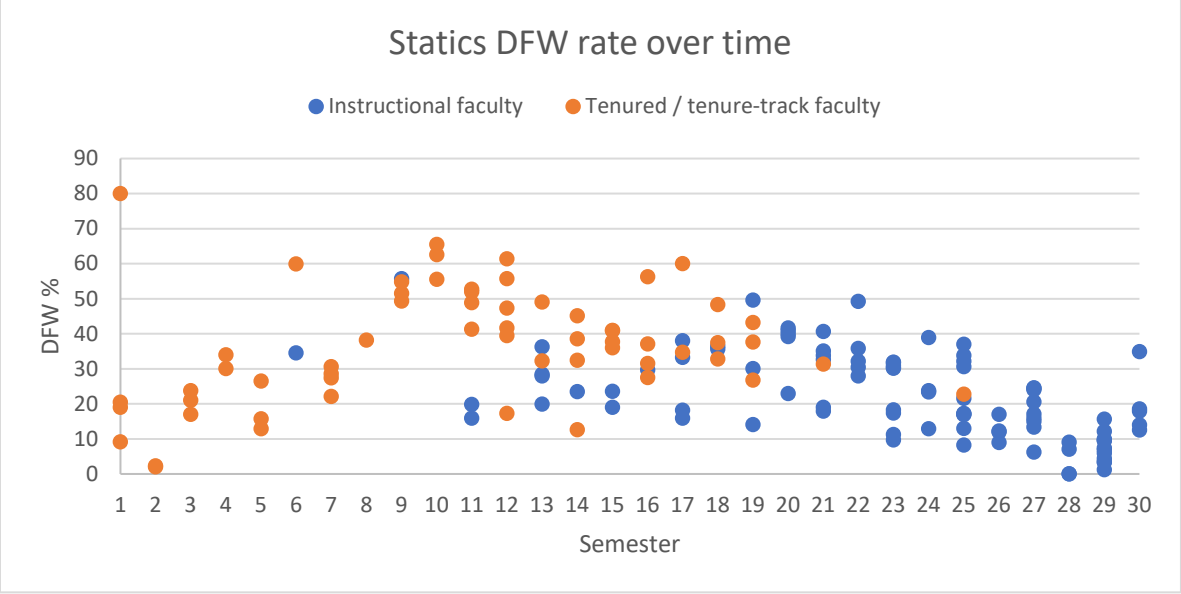

Figure 2: Statics DFW rate in each semester (Fall 2006 to Spring 2021), separated by faculty group. Each dot represents one section of the course.

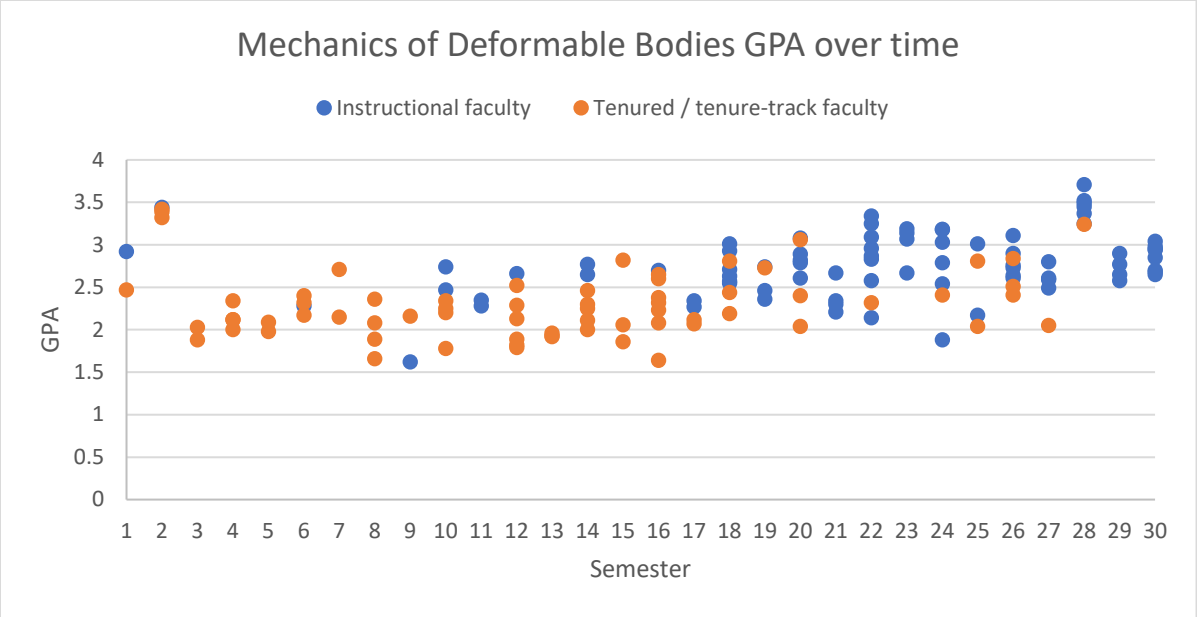

Figure 3: Mechanics of Deformable Bodies GPA in each semester (Fall 2006 to Spring 2021), separated by faculty group. Each dot represents one section of the course.

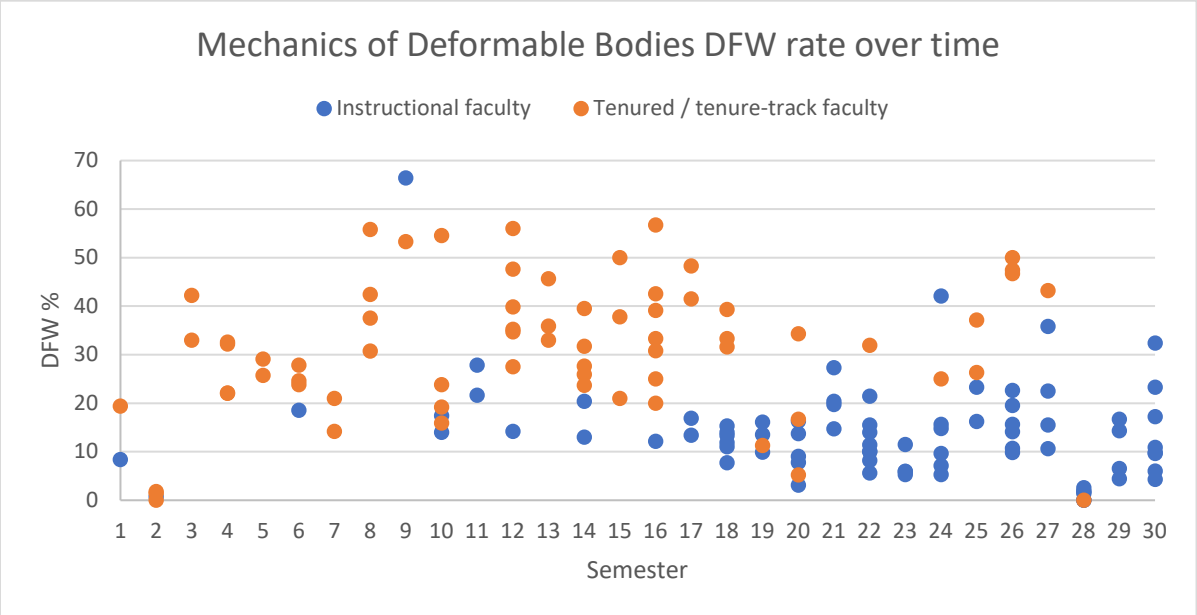

Figure 4: Mechanics of Deformable Bodies DFW rate in each semester (Fall 2006 to Spring 2021), separated by faculty group. Each dot represents one section of the course.

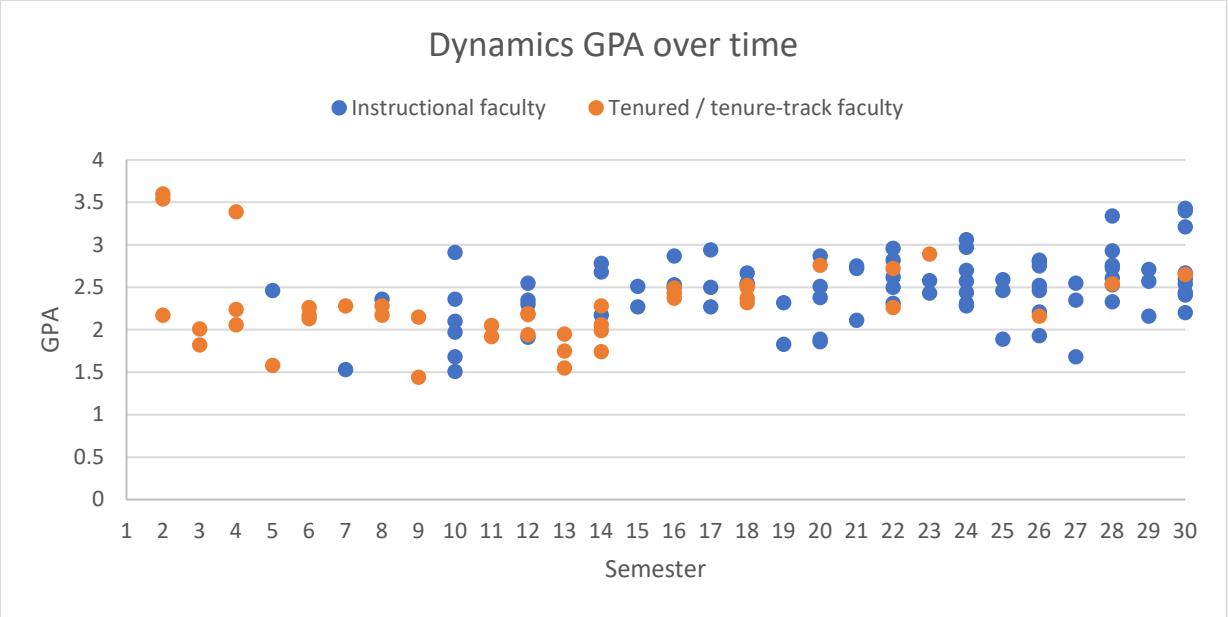

Figure 5: Dynamics GPA in each semester (Fall 2006 to Spring 2021), separated by faculty group. Each dot represents one section of the course.

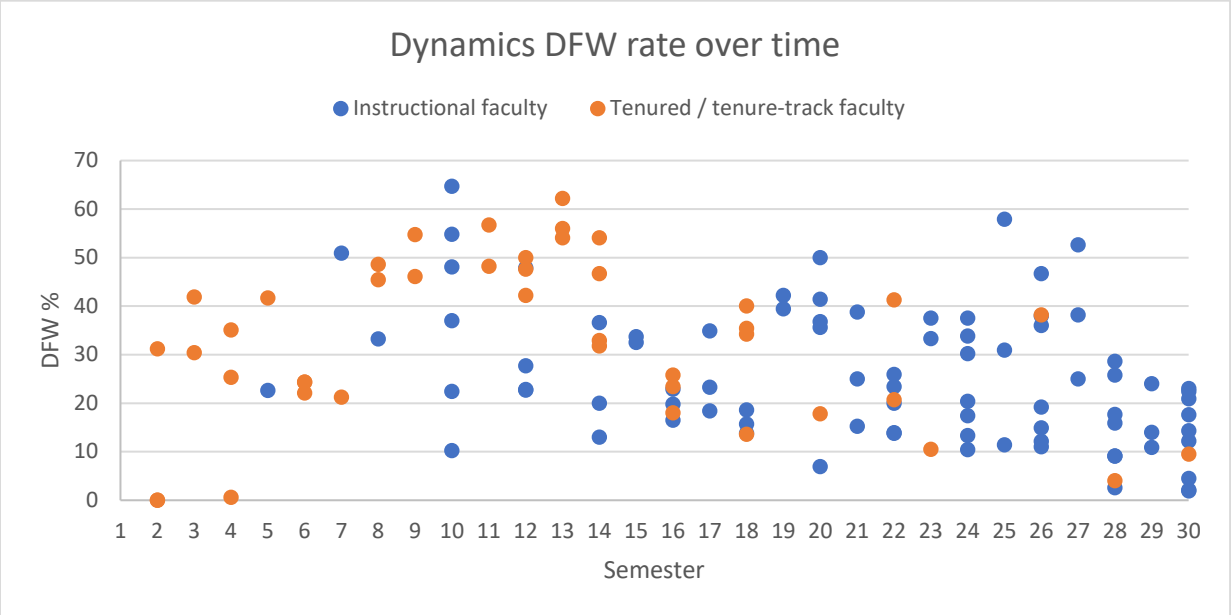

Figure 2: Dynamics DFW rate in each semester (Fall 2006 to Spring 2021), separated by faculty group. Each dot represents one section of the course.

The mean GPA, mean DFW rate, and mean section enrollment for all three courses is shown in Table 3, separated by faculty group. In every course, mean GPA was higher and mean DFW rate lower when the course was taught by full-time NTT faculty. T/TT faculty had larger class sizes than NTT faculty. Single-factor ANOVA tests revealed that all differences were statistically significant, except for the mean enrollment in Mechanics of Deformable Bodies.

	Course					
	Statics		MDB		Dynamics	
	Inst.	T/TT	Inst.	T/TT	Inst.	T/TT
GPA mean (st. dev)	2.63 (0.37)	2.18 (0.45)	2.78 (0.38)	2.30 (0.40)	2.48 (0.39)	2.28 (0.46)
	$p < 0.001$		$p < 0.001$		$p = 0.001$	
DFW rate mean (st. dev)	22.3 (7.12)	36.9 (9.14)	13.6 (9.91)	31.4 (13.8)	25.5 (13.9)	32.7 (16.9)
	$p < 0.001$		$p < 0.001$		$p = 0.011$	
Mean enrollment (st. dev)	84 (37)	151 (83)	73 (33)	82 (47)	67 (32)	86 (46)
	$p < 0.001$		$p = 0.156$		$p = 0.006$	

Table 3: GPA and DFW rate means (st. dev) for each course, separated by faculty group

There was a mild negative correlation between class size and GPA in Statics ($r(153) = -0.24$) and Mechanics of Deformable Bodies ($r(147) = -0.26$). There was no significant correlation in Dynamics ($r(125) = -0.03$).

There was a mild positive correlation between class size and DFW rate in Statics ($r(153) = 0.21$). There was no significant correlation in Mechanics of Deformable Bodies ($r(147) = 0.15$) or Dynamics ($r(125) = 0.05$).

Since class size showed some correlation with both GPA and DFW rate, and T/TT faculty had larger classes on average, we separated our data by class size into groups of 50. We conducted further analysis in cases where we had data for at least 5 sections of each class size for both T/TT faculty and for full-time NTT faculty.

Results for Statics are shown in Table 4. For section sizes of 51 – 100 students we identified 59 sections taught by full-time NTT faculty and 22 sections taught by T/TT faculty. There was no significant difference in mean enrollment between the two groups (73 and 70 respectively). Mean GPA was higher for the NTT group (2.63 vs. 2.24), while mean DFW rate was lower for the NTT group (21.5 vs. 37.9).

For section sizes of 101 – 150 students we identified 20 sections taught by full-time NTT faculty and 9 sections taught by T/TT faculty. There was no significant difference in mean enrollment between the two groups (136 and 126 respectively). Mean GPA was higher for the NTT group (2.57 vs. 2.13), while mean DFW rate was lower for the NTT group (25.5 vs. 39.2).

	Statics			
	51 – 100 students		101 – 150 students	
	Inst.	T/TT	Inst.	T/TT
GPA mean (st. dev)	2.63 (0.38)	2.24 (0.37)	2.57 (0.35)	2.13 (0.69)
	$p < 0.001$		$p = 0.033$	
DFW rate mean (st. dev)	21.5 (12.7)	37.9 (13.3)	25.5 (9.65)	39.2 (23.6)
	$p < 0.001$		$p = 0.032$	
Mean enrollment (st. dev)	73 (11)	70 (12)	136 (14)	126 (14)
	$p = 0.37$		$p = 0.095$	

Table 4: Mean GPA, DFW rate, and enrollment for Statics, separated by class size and faculty group.

Results for Mechanics of Deformable Bodies are shown in Table 5. For section sizes of 1 – 50 students we identified 20 sections taught by full-time NTT faculty and 18 sections taught by T/TT faculty. NTT sections had higher enrollment in this group (37 vs. 28). Mean GPA was higher for the NTT group (2.71 vs. 2.40), while mean DFW rate was lower for the NTT group (13.8 vs. 34.8).

For section sizes of 51 – 100 students we identified 53 sections taught by full-time NTT faculty and 28 sections taught by T/TT faculty. NTT sections had higher enrollment in this group (80 vs. 72). Mean GPA was higher for the NTT group (2.83 vs. 2.33), while mean DFW rate was lower for the NTT group (12.7 vs. 29.2).

For section sizes of 101 – 150 students we identified 5 sections taught by full-time NTT faculty and 16 sections taught by T/TT faculty. There was no significant difference in mean enrollment between the two groups (124 for both). Mean GPA was higher for the NTT group (2.47 vs. 2.18), while mean DFW rate was lower for the NTT group (19.0 vs. 31.5).

	Mechanics of Deformable Bodies					
	1 – 50 students		51 – 100 students		101 – 150 students	
	Inst.	T/TT	Inst.	T/TT	Inst.	T/TT
GPA mean (st. dev)	2.71 (0.46)	2.40 (0.37)	2.83 (0.29)	2.33 (0.48)	2.47 (0.23)	2.18 (0.27)
	$p < 0.001$		$p < 0.001$		$p = 0.049$	
DFW rate mean (st. dev)	13.8 (10.3)	34.8 (13.7)	12.7 (6.79)	29.2 (15.4)	19.0 (5.99)	31.5 (12.7)
	$p = 0.027$		$p < 0.001$		$p = 0.044$	
Mean enrollment (st. dev)	37 (9)	28 (12)	80 (15)	72 (12)	124 (15)	124 (15)
	$p = 0.018$		$p = 0.026$		$p = 0.97$	

Table 5: Mean GPA, DFW rate, and enrollment for Mechanics of Deformable Bodies, separated by class size and faculty group.

Results for Dynamics are shown in Table 6. For section sizes of 1 – 50 students we identified 28 sections taught by full-time NTT faculty and 8 sections taught by T/TT faculty. There was no significant difference in mean enrollment between the two groups (34 for both). There was no significant difference in GPA (2.50 and 2.52 respectively) or DFW rate (24.3 and 22.3 respectively).

For section sizes of 51 – 100 students we identified 51 sections taught by full-time NTT faculty and 26 sections taught by T/TT faculty. There was no significant difference in mean enrollment between the two groups (79 and 76 respectively). Mean GPA was higher for the NTT group (2.50 vs. 2.14), while mean DFW rate was lower for the NTT group (25.6 vs. 38.2).

	Dynamics			
	1 – 50 students		51 – 100 students	
	Inst.	T/TT	Inst.	T/TT
GPA mean (st. dev)	2.50 (0.43)	2.52 (0.47)	2.50 (0.36)	2.14 (0.36)
	$p = 0.77$		$p < 0.001$	
DFW rate mean (st. dev)	24.3 (15.7)	22.3 (18.5)	25.6 (13.0)	38.2 (14.3)
	$p = 0.90$		$p < 0.001$	
Mean enrollment (st. dev)	34 (12)	34 (13)	79 (14)	76 (14)
	$p = 0.99$		$p = 0.49$	

Table 6: Mean GPA, DFW rate, and enrollment for Dynamics, separated by class size and faculty group.

When analyzing data grouped by class size, there were no significant correlations between class size and GPA or class size and DFW rate within each group for any courses or class size groups.

Discussion & Conclusions

We investigate student achievement, as measured by GPA and DFW rate, in large multi-section foundational mechanics courses. We compare results when the classes are taught by T/TT faculty to when the classes are taught by full-time NTT instructional faculty. Students in class sections taught by the NTT faculty on average consistently achieved higher grades and lower DFW rates. This relationship held when we compared class sections of similar sizes. This was true for courses in Statics, Mechanics of Deformable Bodies, and Dynamics.

We show a general trend that GPA decreases and DFW rate increases as class size increases, although correlations are mild. We suggest that, as class sections become very large, it becomes difficult to meet the needs of each student and to make time for every student that needs help outside of class. Reducing class sizes, regardless of who teaches the class, is generally considered beneficial. Since NTT faculty can typically teach more class sections in a semester than T/TT faculty, it is perhaps not surprising that their sections were smaller on average. We suggest this may be an additional benefit of hiring full-time NTT instructional faculty.

There are several possible explanations for the differences seen in this study between faculty groups. The Northwestern study demonstrated that full-time NTT faculty that are well supported by their institution can have positive effects on student learning in both the short-term and the long-term. This is not inconsistent with other studies that have often shown that part-time NTT faculty have positive effects within their class but negative longer-term effects on student achievement. The NTT faculty in our study are full-time, hold Ph.Ds. generally have long-term

relationships with the institution, have a measure of stability in their position, and are encouraged to focus on teaching. It is possible that these factors combine to make them very effective teachers of this material. If this is the case, then hiring similar full-time NTT faculty to teach these large foundational courses might be a cost-effective and productive solution. Although not studied here, this would presumably have the additional benefit of freeing up time for T/TT faculty to teach upper division and graduate courses (which tend to be more specialized and have smaller enrollments) and attend to research and service obligations.

However, this study only looks at results within a particular class and does not investigate longer-term effects. It is possible that NTT faculty are awarding higher grades for reasons not related to student learning. Some authors have suggested that NTT faculty face more pressure to receive good student evaluations, and it has been shown that student's grade satisfaction can affect evaluations and so NTT faculty may feel pressured to inflate grades. In this scenario NTT faculty may actually harm students by depriving them of the deeper learning that is necessary for continued success in subsequent courses.

Limitations & Future Work

Our results show a significant increase in GPA and decrease in DFW rate in courses when the courses are taught by full-time NTT faculty instead of T/TT faculty. However, we do not investigate the effect on subsequent courses. Determining whether such an effect exists will be an important future study, as we cannot otherwise say for certain whether students are actually learning more from NTT faculty in these courses or if they are achieving higher grades for other reasons.

While we discuss potential causes for these differences in general terms, future studies should also attempt to identify more specific differences between NTT and T/TT faculty approaches to teaching. We suggest that NTT faculty are able to devote more time to teaching than their T/TT colleagues, and that this has a generally beneficial effect, but how that time is spent is surely also important. Exploring how faculty groups spend their instructional time and their attitudes towards teaching may yield more thorough understanding of this effect. It may also be interesting to track these effects over time. That is, do these measures change for NTT or T/TT faculty as they become more settled in their position and gain more experience?

Our study is limited to foundational mechanics courses at the 2000 level. Results may not hold for upper-division classes and should not be generalized. The NTT faculty in this study are full-time, receive good institutional support, and are generally experienced. Our results may not apply to part-time NTT faculty or to faculty at different types of institution, such as community colleges.

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