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One Instructor's Qualitative and Quantitative Assessment of a Decade of Teaching Statics at Three Different Institutions

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Abstract

The fundamental nature of Statics may give the impression that offerings of the course at different institutions differ from one another only superficially. While the focus on proper system identification and drawing correct free-body diagrams is virtually universal, this instructor's experience teaching the course at three institutions suggests that there are, in some instances, significant differences in how the course is constructed, taught, assessed, used as a prerequisite for other courses, and catered to the students. In this paper, some of the similarities and differences between these Statics courses are highlighted and qualitative assessments, in the form of instructor observations and student feedback, and quantitative assessments, in the form of student performance on exams and quizzes and preparedness for follow-on courses, are provided. Based on these assessments, the strengths and weaknesses in the Statics course at each institution are identified and recommendations are made to address shortcomings. A comprehensive consideration of assessment tools suggests that (1) imbalance in the course structure, (2) lack of coverage and non-assessment of important topics in Statics at the expense of others, and (3) limited or flawed resources to aid the instructors and students are some of the significant weaknesses identified at these institutions.

Introduction

Statics is *the* fundamental course in a standard mechanical or civil engineering undergraduate curriculum and serves as a gateway to more advanced courses such as Dynamics and Strength of Materials. Much of an instructor's time and effort in a Statics class is dedicated towards teaching students how to properly identify and isolate their systems, both visually by drawing correct free-body diagrams, and analytically through the use of force and moment equilibrium relations to solve for quantities of interest. While this experience is common among faculty who teach the course, every program has its own distinct "flavor" of Statics based on the topics that the faculty have historically considered to be more important for *their* students to learn as they navigate the curriculum. This emphasizing of some topics over others may lead to diverse student learning experiences at different institutions, even when the course is taught by the same instructor.

A review of papers in ASEE's PEER repository and the Journal of Engineering Education indicates that there have been previous efforts to study *elements* of Statics courses in an inter-institutional manner, but not the course as a whole. Dollar et al. [1] reported their experience of blending interactive courseware into their flipped Statics courses at their respective institutions.

d'Entremont et al. [2] describe their process for developing open educational resources in the form of mechanics homework problems at each institution and in collaboration with one another. Even though their paper does not address Statics directly, Besterfield-Sacre et al. [3] investigated the differences in the attitudes of incoming freshman classes at 17 US engineering schools. Much of the rest of the work in the literature involved utilizing concept inventories in Statics instruction across different institutions [4, 5, 6, 7, 8, 9].

As the title of the paper indicates, the author has taught Statics at three very different institutions over the course of about a decade. In the section that follows, the author will provide a brief background of the three institutions and the demographics of the student population at each. This will be followed by a section that summarizes the logistics of the Statics courses at each institution. A section on various quantitative and qualitative assessments of student performance in the course follows after. This work will then be concluded by summarizing some of the strengths and weaknesses of each Statics offering based on the assessments, providing suggestions on potential ways to improve the limitations in the course at each institution, and commenting on the findings in this work from a broader perspective.

A brief look at the institutions and their student populations

The three institutions of interest will be referred to as Institutes A, B, and C throughout this paper. Prior to discussing the similarities and differences in the instruction of Statics, it is important to highlight the very different groups of students that each institution serves. A summary of the most recently available demographic data for each institution is presented in Table 1.

Institute A is, for all intents and purposes, a commuter school with only a small percentage of students residing on-campus. A majority of the students are first- or second-generation immigrants and a significant number are older students and/or the first member of their family to go to college. As defined by Pell Grant stipulations, most students who attend this public institution come from low-income households. Institute A is also considered among the most racially diverse institutions of higher education in the United States. While a larger portion of the student body is female, there are significantly more male students in engineering majors at this institution. The advertised student-to-faculty ratio is 14:1.

Institute B is smaller and much less diverse than Institute A. A large majority of the students are native-born and live on-campus. About one-third of the student body come from low-income households. Most students are from the same state as where Institute B is based and a majority of the rest are from neighboring states. Compared to Institute A, a larger proportion of the student body are engineering majors. Most of the student body in general, and engineering majors in particular, are male. The advertised student-to-faculty ratio is 12:1.

Institute C is a STEM-focused private institution with fewer students than either Institutes A and B. Similar to Institute B, most of the student body is native-born and lives on-campus. The average student also comes from a higher income background compared to students from Institutes A and B; only about one out of every eight students comes from a low-income household. Most students are from a different state than where Institute C is based. The vast majority of the students are engineering majors, with over one-third of the student body pursuing a degree in mechanical engineering. The advertised student-to-faculty ratio is 11:1.

Table 1 2024 demographic information for the undergraduate student population at the three institutions at which the author has taught Statics. This data has been aggregated from collegesimply.com and the individual institution websites.

		Institute A	Institute B	Institute C
Institution type	Size	Mid-size	Mid-size	Small
	Public/Private	Public (city)	Public (state)	Private
	Terms	Semester	Semester	Quarter
Race	White	15%	79%	74%
	Black	16%	4%	2%
	Hispanic	35%	2%	3%
	Asian	25%	3%	4%
	Other	8%	12%	16%
Gender	Male	45%	64%	76%
	Female	55%	36%	24%
Geographic	In-state	90%	74%	29%
	Out-of-state	0%	19%	63%
	International	2%	7%	9%
	Unknown	8%	0%	0%
Economic	Median household income	$48,000	$63,000	$68,000
	Pell Grant recipients	70%	32%	12%
% of student body	in engineering	15%	39%	95%
	in mechanical engineering	3%	4%	35%
	25+ years old	23%	8.1%	0.8%
6-year graduation rate		44%	69%	78%

The Statics course at each institution

As of this work, this instructor has taught Statics a total of eight different terms (always one section per term): four times at Institute A and twice each at Institutes B and C. A summary of the enrollment and administrative information for these sections is provided in Table 2[a].

Which majors take Statics? At the three institutions, mechanical (ME), biomedical (BE), and electrical (EE) engineering majors along with engineering design (ED) and pre-major/undeclared (UN) students were enrolled in Statics. At Institute A, ME and BE majors are required to take this course. The major composition for A-IV, which is the only Institute A section that the author has data for, was 63% ME, 32% BE, and 5% UN. At Institute B, ME majors are required to take Statics, but EE students may take it as an

[a]Due to complexities of gaining approval at three different institutions, neither the institution names nor the year of each iteration of the course will be explicitly identified so that the content presented in this work remains IRB exempt. The sections mentioned in Table 2 are listed chronologically.

Table 2 Enrollment and administrative information regarding the author's Statics courses at the different institutions. Four iterations of the course at Institute A and two iterations each at Institutes B and C are considered.

	Institute A	Institute B	Institute C
Enrollment (Term)	A-I: 15 (Su) A-II: 60 (Sp) A-III: 20 (Su) A-IV: 40 (F)	B-I: 42 (Sp) B-II: 19 (Sp)	C-I: 18 (W) C-II: 26 (W)
Credits	3	3	4
Prerequisites	Calculus II & Physics I	Calculus II	Calculus I
Pre/Co-requisites	Drafting	-	-
Required for	Dynamics Mech. of Matls	Dynamics Strength of Matls	Stat. & Mech. of Matls II Cons. & Acct. Principles [10]
Textbook	Beer and Johnston [11]	Hibbeler [12]	Riley and Sturges [13]
Grading Breakdown	A-I & III | A-II & IV	B-I & II	C-I & II
Homework	-	9%+2%	10%
Quizzes	6 for 35% | 10 for 40%	11 for 20%	-
Midterm Exams	1 for 30% | 2 for 30%	3 for 48%	3 for 45%
Final Exam	35% | 25%	22%	30%
Project	-	-	15%
Computer Problems	2 for 6% | 3 for 12%	-	-

elective. By major, the distribution of students in B-II was 63% UN, 26% ME, and 11% EE (students do not formally matriculate into engineering until the beginning of their junior year). To this instructor's knowledge, most of the students who were pre-major or undeclared in the aforementioned sections at Institutes A and B graduated with a mechanical engineering degree. Lastly, ME and ED majors are required to take Statics at Institute C. However, every student in both sections that were taught by this instructor was an ME major.

When are students supposed to take Statics? A typical mechanical engineering major would register for Statics in the Fall semester of their *sophomore* year at Institutes A and B and in the Winter quarter of their *freshman* year due to the Calculus II and Calculus I prerequisites, respectively.

When did students actually take Statics? 10%, 53%, 20%, and 17% of the students in section A-IV had freshman, sophomore, junior, and senior standing, respectively. At Institute B, this distribution was nearly identical for section B-II: 10%, 53%, 21%, and 16%. Finally, 91% of the students at Institute C were freshman, while the other 9% had sophomore standing between the two sections.

Method of content delivery All but one of these iterations predate the COVID-19 pandemic, but every section was taught fully in-person in a traditional (non-flipped) format. The lectures at Institute A were conducted with students taking notes on their own, while partially-filled lecture packets were handed out at Institutes B and C.

Assessment Types As outlined in Table 2, assessments for this course include homework, quizzes, exams, computer problems, and a project. At Institute A, homework was assigned, but not collected; instead, partial solutions were provided to students due to a limitation of resources, which will be discussed in more detail later. Depending on whether the term was 8 (A-I and III) or 15 (A-II and IV) weeks, 6 or 10 near-weekly 20-minute quizzes, which included one or two workout problems, were conducted at the beginning of the class period. Students were also assessed on their performance on 1 or 2 midterm exams consisting of several workout problems along with a comprehensive final exam. In order to encourage students to take their first steps in learning how to program, 2 or 3 statics problems that required students to use loops and simple commands in MATLAB were assigned as bonus. At Institute B, homework was assigned daily through Pearson's MasteringEngineering® environment that accompanied Hibbeler's textbook. Additional homework was also assigned as bonus for the instructors to be able to grade and critique student solution approaches. Weekly 20-minute quizzes were conducted similar to those from Institute A (some were identical, as will be seen!) along with three midterms and a comprehensive final exam. No project or computer problems were assigned during these iterations of the course. Lastly, at Institute C, homework was assigned daily from the Riley and Sturges textbook. Similar to Institute B, three midterms and a comprehensive final exam were conducted. Additionally, a final project [14] requiring students to design and subsequently test a link element that slowly retracted a landing gear mechanism was assigned to groups of three students.

Common assessments between sections taught by different instructors The author was the sole Statics instructor when iterations A-I, A-II, and A-III were taught. Common exams were held with other instructors during the other five terms.

Course content Table 3 outlines the approximate amount of time, both in minutes and as a percentage of the entire course, spent on major topics and the order in which they were presented to students in the Statics courses at each of the institutions. *To the author's knowledge, Statics continues to be taught in a similar manner to what is outlined in Table 3 to the present day*. There is significantly more class time available during a term at Institute B, so it should not be surprising that the majority of topics at this institution received more attention, especially vectors and vector operations. The list of topics that were covered in the Statics courses at all three institutions are not unusual, but a closer look at the topics that were *not commonly covered* reveals some unexpected choices. At Institute A, nearly one-quarter of the course was dedicated towards determining centroids, centers of gravity, and moments of inertia. Surprisingly, though, simplifying a distributed load to a concentrated load, which is just an extension of equivalent systems and finding the centroid, was never discussed. Furthermore, particle kinematics and the principle of virtual work were both taught towards the end of the course for reasons that are still unclear to this instructor. Lastly, friction received a more extensive treatment at Institute A, since axle, disk, wheel, and belt friction were discussed in addition to the standard Coulomb friction model that is taught in virtually every Statics course. The formal title of the course at Institute C is Statics and Mechanics of Materials I, so a significant portion of it was dedicated to the introductory topics that would typically be covered in a Strength of Materials course. Aside from that, the extensive coverage of frames and machines compared to the other two institutions is a positive, while the fact that equivalent systems of forces was not covered at all seems like a missed opportunity.

Table 3 Approximate amount of time spent on each topic in the Statics course at each institution. The first number in each entry is in minutes, the number next to it in square brackets represents its percentage of the total class time, while the number in parentheses indicates the order in which the topics were covered, so, (1) would be the first topic covered in the course, etc. Topics that were covered in all three institutions are highlighted.

Topic	Institute A	Institute B	Institute C
Vectors and vector operations	100 [5%] (1)	280 [11%] (1)	150 [8%] (1)
2D particle equilibrium	60 [3%] (2)	160 [6%] (2)	100 [5%] (2)
3D particle equilibrium	40 [2%] (3)	60 [2%] (3)	50 [3%] (3)
Moment definition	100 [5%] (4)	160 [6%] (4)	100 [5%] (9)
2D rigid-body equilibrium	100 [5%] (6)	160 [6%] (7)	150 [8%] (10)
3D rigid-body equilibrium	80 [4%] (7)	120 [5%] (8)	100 [5%] (11)
Trusses	150 [7%] (8)	200 [8%] (10)	100 [5%] (12)
Frames and machines	50 [2%] (9)	120 [5%] (11)	150 [8%] (13)
Friction	180 [9%] (10)	160 [6%] (13)	100 [5%] (15)
Centroids and centers of gravity	230 [11%] (12)	160 [6%] (14)	100 [5%] (16)
Equivalent systems of forces	80 [4%] (5)	60 [2%] (5)	-
Simplifying a distributed load	-	100 [4%] (6)	50 [3%] (17)
Moments of inertia (area and mass)	280 [13%] (13)	-	-
Principle of virtual work	100 [4%] (11)	-	-
Kinematics of particles	80 [4%] (14)	-	-
Constraints and static indeterminacy	-	60 [2%] (9)	-
Internal loadings	-	100 [4%] (12)	-
Normal and shear stress definition	-	-	100 [5%] (4)
Stress-strain relation	-	-	50 [3%] (5)
Thermal strain	-	-	50 [3%] (6)
Static indeterminacy of particles	-	-	100 [5%] (7)
Factor of safety	-	-	50 [3%] (8)
Static indeterminacy of rigid bodies	-	-	100 [5%] (14)
Review/Exams/Quizzes	470 [22%]	740 [28%]	400 [20%]
TOTAL in minutes	2,100	2,640	2,000

Assessment of student performance in Statics courses at the three institutions

The primary assessment tool used to evaluate the success of each iteration of the Statics courses in this work is student scores on quizzes and exams. This has been done both from an individual problem and overall performance perspective, as outlined in the next three subsections. These assessments have been supplemented by student performance in follow-on courses, student feedback on course evaluations, and instructor observations.

Quantitative assessment of student performance on similar problems One way to evaluate how well students learned the content is to compare their performance on similar quiz and exam problems involving the common topics at the three institutions. Average scores are tabulated in Table 4 for each section. There is quite a bit of information to unpack here, so some of the more significant topics will be considered separately:

2D particle equilibrium: Sections A-II, A-IV, and B-II all received the same problem on a quiz, which is shown in Figure 1(a). There is a statistically significant difference between the performance of the students in A-IV compared with those in A-II (with a p value of $0.033 < 0.05$[b]) and B-II ($0.014 < 0.05$). Overall, section A-IV struggled with various topics in the course, as will be seen throughout. Students in section A-I also performed especially poorly on a similar question, but this seems to be an outlier for how they did for the rest of the course. There is no statistically significant difference between the rest of the results.

3D particle equilibrium: This topic was not tested at all at Institute C, which is a surprising oversight in retrospect. At Institute A, all four sections received a problem similar to one shown in Figure 1(b) on a midterm or final exam. The 3D particle equilibrium problems for B-I and B-II were similar in nature, but geometrically less challenging to those of Institute A; the averages, however, are significantly better. This can perhaps be attributed to the larger amount of time that was spent at Institute B on vectors and vector operations.

3D rigid-body equilibrium/Moment definition: Neither of these topics were tested at Institute A, which means that the only place where students were assessed on any type of 3D problem in Statics was with particle equilibrium. This is clearly not enough.

2D rigid-body equilibrium: Students at all three institutions were given a question similar to the one shown in Figure 1(c) *at roughly the same point in the term* and were asked to determine the tension in the cable, applied couple M, or reactions at the pin holding the bar in place. More than any other, this common problem clearly demonstrates the difference between the level of learning of the students at the three institutions, as captured through the p-values in Table 5. In essence, there is a statistically significant difference between the average performance of the students inter-institutionally, even though the intra-institutional cohort averages are effectively the same.

[b]The p values in this section are calculated based on a Welch's (two-tailed, two-sample, unequal variance) *t*-test, which is used to determine whether two independent Statics sections have mean scores that are *statistically* significantly different from one another ($p < \alpha = 0.05$) assuming that the standard deviation in their scores are different. To use Welch's *t*-test, each section's scores must be normally distributed. The Shapiro-Wilk test [15] has been performed on each cohort's data set to verify that the null hypothesis of normally distributed differences cannot be rejected for $p < \alpha = 0.05$, *i.e.*, it is safe to assume the scores are normally distributed.

Table 4 Assessment average (in percent) on similar quiz [Q], midterm [M], and final exam [F] problems involving topics common to the Statics courses at the three institutions. The standard deviation is included in parentheses next to each entry. Problems that were virtually identical (except for values) are identified with the same number of asterisks for each topic. Section performance on *identical* problems that were (statistically) significantly worse than others is highlighted in red.

Topic	Institute A	Institute B	Institute C
Vector operations (3D vector addition)	Not tested	I: 76.3 (23.5)* [Q] II: 81.1 (27.2)* [Q]	I: 78.4 (17.9) [M] II: 80.2 (20.1) [M]
2D particle equilibrium (Weight on cables)	I: 66.3 (30.7) [Q] II: 80.5 (19.6)* [Q] III: 78.2 (23.2) [Q] IV: 68.3 (31.5)* [Q]	I: 78.3 (14.6) [Q] II: 83.3 (13.8)* [Q]	I: 77.2 (21.0) [M] II: 76.0 (18.8) [M]
3D particle equilibrium (Weight on cables)	I: 65.0 (19.7)* [F] II: 52.4 (24.9)* [F] III: 62.5 (27.7)* [M] IV: 70.5 (22.8)* [M]	I: 88.3 (19.1) [M] II: 89.5 (16.3) [M]	Not tested
Moment definition (Calculating 3D moment)	Not tested	I: 68.9 (15.2)* [Q] II: 66.6 (21.9)* [Q]	I: 65.4 (21.0) [M] II: 68.1 (36.6) [F]
2D rigid-body equilibrium (Pinned bar and cable)	II: 63.4 (20.3)* [Q] III: 81.4 (15.0) [M] IV: 57.2 (21.4)* [Q]	I: 72.3 (17.3)* [Q] II: 72.4 (24.6)* [Q]	II: 90.5 (12.2)* [M]
3D rigid-body equilibrium (Rod with bearings)	Not tested	I: 59.6 (33.4)* [F] II: 68.8 (19.0)* [M]	I: 77.7 (20.8) [M] II: 80.3 (20.7) [M]
Trusses (Method of joints and sections)	I: 73.5 (16.5)* [M] II: 68.2 (21.5)** [M] III: 67.6 (18.3)* [M] IV: 72.3 (22.1)** [M]	II: 78.6 (20.3)* [M]	I: 87.5 (11.0) [F] II: 89.0 (15.1) [F]
Frames and machines (2D frame)	IV: 54.0 (22.2)* [M]	I: 75.9 (16.6)* [Q] II: 86.8 (12.2)* [Q]	I: 86.3 (12.8)* [M]
Friction (Coulomb friction)	I: 66.1 (24.7) [Q] II: 65.0 (16.9)* [Q] III: 70.3 (17.2)* [Q] IV: 53.2 (19.6)* [Q]	I: 81.6 (16.2)* [Q] II: 76.8 (15.1)* [Q]	I: 91.4 (17.4) [M] II: 86.6 (18.2) [M] [moment eq. required]
Centroids and CoG's (Composite shape centroid)	I: 80.8 (12.6) [F] II: 80.3 (15.5) [F] III: 84.4 (14.5) [F] IV: 83.7 (15.2) [F]	I: 80.1 (24.6)* [F] II: 90.1 (22.7)* [Q]	I: 100 (0.0)** [F] II: 84.6 (36.8)** [F] [multiple choice]

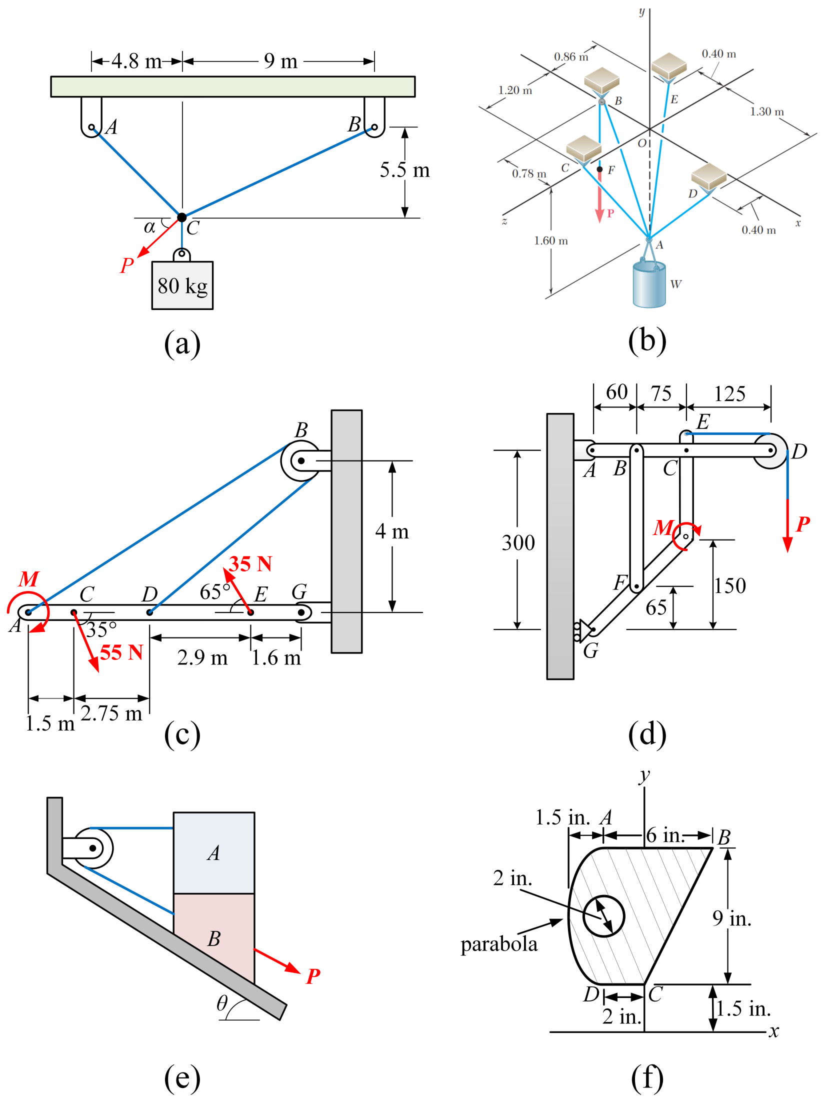

Figure 1 Common problems assessed in Statics: (a) 2D and (b) 3D (Problem 2.123 from Beer and Johnston [11]) particle equilibrium (weight hanging from cables), (c) 2D rigid-body equilibrium (pinned bar supported by cable), (d) 2D frame, (e) friction (blocks on top of each other), and (f) centroid of a composite shape.

Frames and machines: Students at all three institutions also saw the same 2D frame as the one in Figure 1(d). The average scores closely track with those from the 2D rigid-body equilibrium, which is not surprising since a frame is simply a collection of 2D rigid bodies.

Friction: The focus on the type of Coulomb friction problems that were taught and assessed was somewhat different between the institutions. At both Institutes A and B, most problems involved understanding how to deal with the impending motion of a particle so a moment balance would not be necessary. At Institute C, much of the discussions on this topic revolved around whether an object would slip or tip first, which necessitates applying both a force and moment balance. Students at Institutes A (except A-I) and B all received a

Table 5 Two-tailed two-sample unequal variance p-values between the means of sections who received the same 2D rigid-body equilibrium problem.

	A-II	A-IV	B-I	B-II	C-II
A-II	N/A				
A-IV	0.151	N/A			
B-I	0.019	<0.001	N/A		
B-II	0.16	0.028	0.987	N/A	
C-II	<0.001	<0.001	<0.001	0.007	N/A

problem similar to the one shown in Figure 1(e) on a quiz. There was a significant change in score between the quiz and final exam score on the friction problem for section A-IV, which leads one to consider whether this is a common occurrence for every topic that was assessed more than once during the term. This will be discussed further in the next subsection.

Centroids and centers of gravity: This topic was covered either at or very near the end of the term in all eight iterations of the course. The assessment always involved determining the centroid of a shape comprised of simpler common shapes, similar to the one shown in Figure 1(f), which was a quiz question for both B-I and B-II. It is noteworthy to mention that it would not have been possible to give students at Institute C a problem that required integration to determine the centroid since the prerequisite to Statics is only Calculus I.

EVALUATING PERFORMANCE ON THE SAME TOPICS OVER DIFFERENT ASSESSMENTS While the data presented in Table 4 provides a valuable insight on comparing student performance on similar (and often identical) problems at different institutions, it only gives a snapshot of how students performed on a particular problem during one of the assessments. It would be useful to explore how students at Institutes A and B performed on problems involving the same topic through different assessments (quizzes, midterm exams, and the final exam). A summary of this information is tabulated in Table 6. Considering the overall picture, student performance improved on most topics in each section after revisiting them. Part of this may be attributed to students taking the exams more seriously than the weekly quizzes because they were worth a larger percentage of the grade. It may also be due to students having less time to absorb the topics that they were quizzed on because they frequently occurred less than a week after a topic was first introduced. Having said this, though, the outlier cases in Table 6 can mostly be attributed to problems that involved non-trivial geometry or those that looked “different enough” from the homework and class problems that many students struggled to work through.

ASSESSMENT OF OVERALL STUDENT PERFORMANCE IN THE COURSE The average scores on the significant assessment components for all eight sections are summarized in Table 7. For sections A-I, A-III, B-I, and B-II, the lowest quiz score was dropped; the lowest two scores were dropped for sections A-II and A-IV. Homework (Institutes B and C), computer problems (Institute A), and the final project (Institute C) grades are not shown.

Table 6 Average score (in percent) on problems involving the same topic in quizzes, midterm exams, and the final exam for sections at Institutes A and B. The standard deviation is included in parentheses next to each entry. Failing mean scores have been highlighted in red.

Section	Topic	Quizzes	Midterm Exams	Final Exam
A-I	Truss	62.5 (22.4)	73.5 (16.5)	
	Friction	66.1 (24.7)	71.5 (20.8)	82.5 (16.8)
	Centroid	82.6 (15.6)		80.8 (12.6)
A-II	3D particle equilibrium	63.6 (29.6)	82.0 (16.2)	52.4 (24.9)
	2D rigid body	63.4 (20.3)	75.4 (31.2)	66.9 (29.6)
	Truss	57.4 (22.1)	68.2 (21.5)	
	Friction	65 (16.9)	80.4 (20.4)	80.1 (15.7)
	Centroid	72.5 (19.6)	77.4 (15.5)	80.3 (15.5)
A-III	Friction	70.3 (17.2)	85.2 (16.1)	84.3 (11.3)
A-IV	3D particle equilibrium	57.1 (29.6)	70.5 (22.8)	
	2D rigid body	57.2 (21.4)	81.9 (15.9)	75.8 (17.3)
	Truss	34.1 (22.2)	72.3 (22.1)	
	Friction	53.2 (19.6)	81.9 (15.9)	74.6 (17.8)
	Frame		54.0 (22.2)	51.1 (19.1)
	Centroid	72.5 (19.6)		83.7 (15.2)
B-I	2D particle equilibrium	78.3 (14.6)	92.4 (14.2)	
	2D rigid body	72.3 (17.3)		79.6 (26.1)
	3D rigid body	82.0 (10.1)	77.1 (23.8)	59.6 (33.4)
	Truss	81.6 (16.2)		75.9 (25.5)
	Friction	79.4 (6.8)		63.2 (32.9)
	Centroid	68.7 (24.6)		80.1 (24.6)
B-II	2D particle equilibrium	83.3 (13.8)	97.4 (9.2)	
	3D particle equilibrium	81.1 (27.2)	89.5 (16.3)	
	2D rigid body	72.4 (24.6)	76.1 (18.6)	72.7 (25.8)
	3D rigid body	78.6 (19.5)	68.8 (19.0)	65.1 (19.2)
	Truss	63.4 (19.0)	78.6 (20.3)	
	Frame/machine	86.8 (12.2)	79.2 (25.6)	78.7 (21.0)
	Friction	76.8 (15.1)		81.8 (15.2)
	Centroid	75.5 (18.6)		90.1 (22.6)

There is quite a bit to unpack from the data in Table 7. There was a 4 to 6 point jump in the average quiz scores when one quiz was dropped; this ballooned to 8 to 9 points for the sections where two scores were dropped. Furthermore, there was too much opportunity for extra credit in all sections at Institute A. With the computer problems, students had an opportunity to earn up to 106 (A-I and A-III) or 107 (A-II and A-IV) points in the course. This was done to (1) encourage students to learn how to code and (2) to encourage them to

Table 7 Assessment and course averages (in percent) for the eight sections of Statics course taught at three different institutions. The standard deviation is included in the parentheses next to the average for each entry. The actual quiz column is calculated based on every score, including zeros for unexcused absences. The adjusted column is the score used to calculate the final grade for the course after dropping the lowest score(s).

Section	N	Quizzes (Actual)	Quizzes (Adjusted)	Midterm Exam(s)	Final Exam	Course
A-I	15	72.2 (6.1)	78.3 (13.6)	74.5 (13.2)	79.9 (12.0)	75.7 (10.3)
A-II	60	65.0 (16.5)	73.6 (16.7)	75.7 (16.6)	73.7 (15.2)	75.2 (16.3)
A-III	20	70.5 (12.5)	75.6 (11.7)	74.1 (10.3)	80.0 (10.7)	76.1 (10.7)
A-IV	40	62.4 (14.5)	71.2 (14.9)	69.2 (14.0)	67.3 (11.1)	70.9 (13.9)
B-I	42	69.4 (16.1)	73.6 (14.5)	81.0 (13.9)	72.0 (21.5)	76.7 (14.3)
B-II	19	75.1 (11.0)	79.3 (10.1)	79.5 (10.4)	75.4 (12.0)	77.5 (9.1)
C-I	18	-	-	81.2 (12.2)	82.4 (12.2)	83.5 (8.7)
C-II	26	-	-	81.7 (10.8)	78.9 (15.1)	81.9 (9.3)

stay engaged in the course since homework was not being collected. Looking back regretfully, even with positive intentions, this generosity in grading by this (at the time, very inexperienced) instructor led to some students at Institute A receiving a higher grade than their demonstrated level of content comprehension on the quizzes and exams. This was much less pronounced for the students at Institute B, since all the quizzes combined were only 20% of their final grade, and even more so for the students at Institute C, who only had one of their 19 homework submissions dropped.

Comparing students at the three institutions, it is clear that those at Institute C performed statistically better than their counterparts at Institute A on the midterm exams (all sections), final exam (sections A-II and IV), and for the course as a whole (least significant mean difference: $p = 0.061$). Compared to the students at Institute B, the cohort at Institute C performed about as well on the midterm exams (both sections), scored significantly better than the B-I iteration on the final exam and for the entire course. Noting once more that most of the students at Institute C were freshmen compared to both Institutes A and B, the data is conclusive: on average, the students at Institute C were academically better prepared and performed at a higher level compared to their counterparts. This is not a surprising conclusion. Each institution caters to particular groups of students with different backgrounds and levels of preparedness, as highlighted in an earlier section. Simply put, at a high-tuition, STEM-focused institution (C), the majority of the students are generally going to be better prepared, receive more individual support and attention, and have access to more resources than their counterparts.

(An attempt at) assessing student preparedness in follow-on courses While evaluating student performance in this instructor's Statics courses has been straightforward due to a plethora of data, assessing student preparedness and performance in follow-on classes such as Dynamics, Mechanics of Materials, and Conservation and Accounting Principles is more challenging since the author did not necessarily teach those courses and a significant time has elapsed since most iterations of the course have been taught. Below is the author's best attempt at piecing together information to provide a sense of student preparedness in follow-on courses:

Institute A: The author was unable to collect quantitative data about student performance in a follow-on course for any of the four cohorts at Institute A. However, the author *was an undergraduate student at Institute A* prior to teaching Statics and can provide some sense of his own preparedness for the Dynamics and Mechanics of Materials courses that followed. While teaching Statics, this instructor relied heavily on his own student notes and course arrangement, which means that all four sections should have had, at least in theory, an experience that closely mirrored the author's. As a student, the author found both Dynamics and Mechanics of Materials to be much more challenging than Statics. The Dynamics course began with particle kinematics, which made the time that was spent on the topic in Statics feel superfluous. The author found that Statics had otherwise been a good preparation for Dynamics, because the difficulty in the course stemmed mostly from topics related to the motion of the system, *e.g.*, kinematics associated with different coordinate systems, instantaneous centers, etc. The class time that was dedicated towards determining centroids and moments of inertia in Statics came in handy when it was time to determine bending stresses in different composite cross-sections in Mechanics of Materials, but that occurred a few weeks into the course, by which point the author was struggling on more elementary topics. Introducing internal loads and the basic definition of stress and strain in Statics would have allowed more of an adjustment period towards these topics, although it would have still probably been a tough course to navigate.

Institute B: The author obtained data for a subset of 11 students in the B-I cohort who took Strength of Materials (not with the author) in the Fall term that followed. The remaining students either did not pass Statics, transferred out of Institute B, took Strength of Materials in another term, or were enrolled in a major that did not require Strength of Materials. The performance of this subset of students in Strength of Materials and their peers, who took Statics in the same term as the B-I cohort with another instructor, is shown in Table 8.

Table 8 Performance of two subsets of Statics students (B-I cohort and their peers taught by a different instructor) in Strength of Materials. The standard deviation is included in parentheses next each average. The final class grade is based on converting student letter grades to a 4.00 scale.

	B-I subset	Other instructor subset
Number of students	11	16
GPA [out of 4.00]	2.80 (0.52)	2.91 (0.66)
Free-body-diagram assessment score	76.3% (12.9%)	78.1% (10.0%)
Final class grade [out of 4.00]	2.51 (0.73)	2.14 (1.16)

Both groups of students in Table 8 took a Statics assessment quiz on the first day of Strength of Materials. This assessment consisted of 14 questions, 9 of which included drawing free-body diagrams of particles, rigid bodies, truss joints and sections, frame and machine members, and the section of a bar. The remaining problems concerned resolving forces into components, determining 2D and 3D moments about a point, simplifying a distributed load, and determining the centroid location of a composite shape. The mean score on the free-body diagram questions was roughly the same for the two groups and in general agreement with how they performed in Statics. While the final letter grade for the B-I subset was better, neither group has a large enough sample size for a definitive judgment. On the whole, however, these numbers *suggest* that the B-I cohort was competent in their knowledge of free-body diagrams to tackle the rigors of Strength of Materials.

Institute C: Years prior to this work, a faculty member at Institute C looked at historical data to study the correlation between student grades in Statics and its follow-on course, Conservation and Accounting Principles. This internal study found a weak correlation between a student's grade in Statics and their preparedness and performance in Conservation and Accounting Principles. The author taught both courses to 5 students in the C-II cohort. The Pearson correlation coefficient between these students' final grades for the two courses is 0.921, indicating a very strong positive correlation.[c] The author, however, trusts their colleague's conclusion since they looked at a much larger sample size.

QUALITATIVE ASSESSMENT OF THE COURSE - STUDENT FEEDBACK This instructor received feedback via evaluations that were completed at the end of the term from five of the eight cohorts (all but A-I, A-II, and A-III). The feedback on the various aspects of the course and instructor, including organization, availability, handling questions, care for student success, and helpful teaching methods were very positive on the Likert-scale questions for all five sections, so much so that no meaningful insight will be gained by presenting a detailed breakdown of those values. However, all five cohorts provided important feedback in the form of free response comments, some of which is highlighted:

Institute A: Students from section A-IV were asked to "list the three most important things learned" in their evaluations. These topics have been distilled down to the bar graph in Figure 2. Most students encountered topics other than free-body diagrams and equilibrium for the very first time in Statics, *i.e.*, the definition of a moment, dealing with 3D systems, equivalent systems of forces, and even coding in MATLAB. Students were also asked about what they appreciated most about the course and suggestions for improvement. The positive comments highlighted various aspects of the instructor's teaching style and feedback provided on graded work. Suggestions for improvement included requests for more time on the quizzes, additional recitation sessions, and assigning less weight to the quizzes.

Institute B: The open-ended questions asked students about what helped them learn in the course and suggested changes to improve learning. The instructor, the partially-filled lecture packet, and the more challenging in-class examples were commonly highlighted by

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[c]This coefficient is used to determine the strength of a *linear* relationship between two variables. It has been used here since grades from the same 5 students has been considered (data is paired). This coefficient assumes the data to be roughly normally distributed, which is admittedly difficult to establish when the sample size is this small.

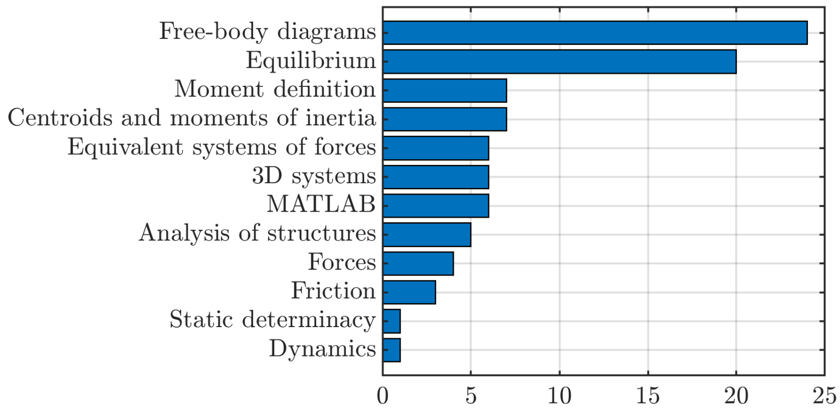

Figure 2 Number of A-IV students who mentioned the topics shown as one of the three most important things they learned in the course (36 respondents)

students of the two sections as being helpful to their learning. The most common suggestion for improving learning was eliminating the MasteringEngineering component of the course. Many students found the software to be too buggy and more time consuming than submitting written homework. A lot of the same students, however, made a point to mention that they understood why there was a need for something like MasteringEngineering from the instructor perspective: a limitation of resources, namely teaching assistants.

Institute C: At this institution, students provided open-ended comments to questions involving the quality of learning, strengths of the course, improvements that could be made, and rating for the instructor. Both the quality of learning and instructor rating comments praised the structure of the course and the instructor's organization and effective use of teaching methods that helped the students learn the material. Students singled out the partially-filled lecture packet, the muddiest points documents that this instructor wrote up to explain topics that students were still confused about in more detail, and the final project, which students found to be an interesting, real-world application of the theory they had learned in class, as strengths. Most comments for improvements had to do with too much homework being assigned (two to three per lecture period).

ASSESSMENT OF THE COURSE AND STUDENTS - INSTRUCTOR PERSPECTIVE Not all of this instructor's efforts at each institution has been captured in the preceding subsections. The account below is an attempt to give a clearer picture of some of these experiences:

Institute A: Teaching Statics at Institute A was a unique experience: there was virtually no input in deciding the content that was to be taught in Statics, but there was also almost no supervision in how the class was taught. This allowed the author to try different grading schemes and teaching techniques with little pushback. For sections A-II, A-III, and A-IV, students were told on the first day of the class that their letter grade for the course will be based on their numerical course score rank compared to their peers and that only x% of the class will receive A's, y% B's, etc. They were further informed that the logic behind this was to not only discourage cheating, but to have students understand that in the real world, nothing is absolute. The author believes that this grading approach was, to a large degree, successful in pushing students who had the drive to do better. The author also struggled with managing larger sections (A-II and A-IV) because of a lack of any type of departmental or institutional support. Grading assessments was time consuming and holding office hours and responding to emails would occasionally be overwhelming. As for the students, the two Summer term sections (A-I and A-III) were excellent: most were responsible, participated in class discussions, and ultimately passed the assessments. There were, unfortunately, a large number who struggled in sections A-II and A-IV. A total of 15 students combined received a failing grade and another 9 would not have passed without dropping the lowest quiz scores or extra credit from the computer problems. Under the circumstances, outside of writing messages like "please stop by if you need help" on returned work, it was regretfully not possible to do something more tangible. Most of those who passed Statics were able to complete their degree and many who have remained in contact are employed in engineering-related fields in the same city.

Institute B: The author grew significantly as an instructor after moving to Institute B, due to additional experience, being given more responsibility, and having input into the design and teaching of assigned courses. Final grades were assigned in a traditional (non-rank-based) format. In order to allow for more time to work on problems in class, the author compiled partially-filled note packets. Students in both sections would generally engage in class discussions when prompted, but would rarely work on in-class problems on their own. These students had higher expectations about office hours and email help compared to those at Institute A. Overall, a total of 6 students between the two sections received a failing grade in the course. There were more resources, such as individual advisors and mental health specialists, available at Institute B, so dealing with struggling students was less of a challenge for the instructor. To the author's knowledge, most of the students in those Statics classes completed their degrees and a majority of those who have remained in contact are employed in engineering-related fields in the same or neighboring states.

Institute C: The author continued to gain experience and improve as an instructor after transitioning to Institute C, which provided a very collaborative environment in which faculty constantly tinker with courses and teaching methods to deliver the best possible experience to the students. The author expanded the use of partially-filled note packets and also employed muddiest points documents. This instructor found students at Institute C (and not just in Statics) to be academically stronger, better prepared, more inquisitive, and generally more engaged in class discussions compared to their Institute A and B counterparts, even though most were just in their second term of college. Nearly every student would work on in-class problems on their own when asked to do so. This group of students had higher expectations about instructor availability outside of class compared to those at Institutes A and B. Overall, just 2 students between the two sections failed the course. A lot of resources, including different types of tutors, individual advisors, and mental health specialists, were available to this group of students. To the author's knowledge, nearly every student who passed Statics eventually completed their degree. Those who have remained in touch have either attended graduate school or are employed in engineering-related fields all around the country.

Conclusion and Recommendations

In this work, a detailed assessment of the author's decade-long experience teaching eight sections of Statics at three different institutions was discussed. This included quantitatively evaluating the performance of students at different institutions on similar problems, on the same topics over different assessments, and in the course as a whole. Qualitative assessments of the course based on student feedback and instructor observations along with student preparedness in follow-on courses were also considered. Based on these assessments, from an institute and program perspective, the author has identified the following strengths (S) and weaknesses (W) in each Statics course along with suggestions that will hopefully provide a better teaching experience for the instructors and more fruitful learning for the students:

Institute A:

- (S) Quizzes, midterm exams, and the final exam provide multiple assessment opportunities for the instructor and chances for the students to demonstrate their understanding.
- (S) Computer problems provide an early opportunity for students to combine the theory from the lectures with a programming assignment.
- (S) Coverage of moments of inertia better prepares students for Mechanics of Materials.
- (W) The course generally feels unbalanced. For example, spending nearly a quarter of the class on centroids, centers of gravity, and moments of inertia seems excessive, while only 2% of lecture time is dedicated to frames and machines.
- (W) Simplifying a distributed load should be covered as part of Statics. A suggestion would be to teach this topic instead of the principle of virtual work.
- (W) Exposure to internal loads or the definition of normal and shear stress in Statics would be helpful for the early portion of Mechanics of Materials. A suggestion would be to teach this topic instead of particle kinematics.
- (W) Students are never assessed on their ability to calculate moments due to forces in space or determine any type of 3D reactions. It is recommended that one quiz address calculating moments and a midterm or final exam problem be on 3D rigid-body equilibrium.
- (W) [*for the program*] The author's experience boils down to a simple equation: Lots of underprepared students + an inexperienced instructor + no additional resources/oversight = (possible) recipe for disaster. Assigning an experienced faculty mentor and hiring teaching assistants, even undergraduate students, could help alleviate some of the pain for everyone.

Institute B:

- (S) This was most balanced Statics course in terms of coverage out of the three considered.
- (S) Every topic, especially vectors and vector operations, receives extensive lecture time.
- (S) Quizzes, midterm exams, and the final exam provide multiple assessment opportunities for the instructor and chances for the students to demonstrate their understanding.

- (W) The course lacks an application that the students can further engage with. Assigning problems that require programming would be low-hanging fruit. A final project that utilizes the theory discussed in class would be even better.
- (W) [*for the program*] With all due respect to the wonderful folks at Pearson, utilizing MasteringEngineering instead of assigning and collecting more extensive written homework as a way to make do with having fewer teaching assistants did not help the students learn the content better. If anything, it antagonized them. If it is not possible to get more help, utilizing a different grading scheme or assigning a problem similar to one of the homework problems as a quiz may be better alternatives.

Institute C:

- (S) The course is arranged and balanced nicely in the way it combines Statics with introductory elements of Mechanics of Materials.
- (S) The final project incorporates design, topics related to Statics (two-force member and 2D rigid-body equilibrium), Mechanics of Materials (stress, strain, and factor of safety), and teaming into a package that students ultimately appreciate and learn from.
- (S) Student demonstration of knowledge is generally better than those of Institutes A and B.
- (W) Equivalent systems of forces should be covered as part of an undergraduate Statics course. A suggestion would be to teach this topic in place of one of the project work days.

Taking a broader perspective than proposed improvements for specific institutions, several lessons have emerged that are transferable to other programs and instructors. First, institutional constraints such as curriculum rigidity, the student population being served, and resource availability, significantly affect performance in a core engineering course such as Statics and there is only so much that any instructor can do to overcome these challenges. Second, a perfect Statics course is a myth; however, it would be a valuable exercise for the stakeholders to consider all the topics covered in the course similar to what is outlined in Table 3 along with assessment types and work outside of the classroom every few years to ensure that the course continues to serve its purpose. Lastly, providing encouragement and mentorship to new faculty and giving them room to try new approaches, within the aforementioned institutional constraints, is vital to their development as teachers. Failure to do so will only encourage those who care to explore other opportunities. Collectively, these lessons highlight how the impact of faculty efforts to improve student learning can be blunted by institutional inefficiencies and an inequitable distribution of resources for students and their instructors.

This leads the author to a more consequential conclusion: *generally* speaking, students who come from a more privileged background are not only better prepared for the rigors of Statics (and almost certainly college in general), but their self-selection into attending schools with more resources and a better support structure for students and faculty (like Institute C) allows them to maintain an advantage over those who choose schools like Institute B and especially Institute A. Results show that while students at Institutes A and B are, for the most part, able to (1) demonstrate improvement in their grasp of the fundamental topics by the end of Statics and (2) utilize what they learned in succeeding classes, there is still a discernible difference in these students' ability to do analysis and design compared to their counterparts in downstream courses. Drawing from personal experience, even *after graduating* at the *top* of their class from Institute A, the author truthfully would not have been able to solve many of the basic analysis problems that an *average* student at Institute C could after completing Conservation and Accounting Principles in their *sophomore* year. More importantly, although it is still too early to make a definitive judgment, this difference seems to extend to career opportunities and lifetime earning potential, at least with respect to the former students that have remained in touch over the years.

In closing, as the author reflects back on this wonderfully eclectic journey, they would like to extend their sincere gratitude to the 240 students whose experiences in their Statics courses have been captured in this paper, the 6 instructors who co-taught the class with them, and the 3 institutions who hired them. Every one of those students, colleagues, and institutions has played a role in an incredible formative experience that has shaped this instructor's ever growing love for teaching. To many more years of teaching Statics!

References

[1] A. Dollar, R. R. Ulseth, and P. S. Steif, "Blending Interactive Courseware into Statics Courses and Assessing the Outcome at Different Institutions," in *2011 ASEE Annual Conference & Exposition*, (Vancouver, BC), ASEE Conferences, June 2011.

[2] A. G. d'Entremont, A. S. Webb, S. Maw, and J. Kirkey, "Building Comprehensive Open Educational Resources in Mechanics: Evaluating Approaches to Problem Development," in *2021 ASEE Virtual Annual Conference Content Access*, (Virtual Conference), ASEE Conferences, July 2021.

[3] M. E. Besterfield-Sacre, M. Moreno, L. J. Shuman, and C. Atman, "Comparing Entering Freshman Engineers: Institutional Differences in Student Attitudes," in *1999 Annual Conference*, (Charlotte, North Carolina), ASEE Conferences, June 1999.

[4] C. H. Ramming, C. Papadopoulos, E. Davishahl, B. P. Self, S. C. MacNamara, M. Silberstein, and J. V. Dannenhoffer, "WIP: Large-scale Development and Deployment of Concept Questions in Statics," in *2020 ASEE Virtual Annual Conference Content Access*, (Virtual Online), ASEE Conferences, June 2020.

[5] C. Papadopoulos, E. Davishahl, C. Ramming, J. B. Abreu, and W. Kitch, "Work in Progress: Context Matters: A Comparative Study of Results of Common Concept Questions in Statics at Several Diverse Institutions," in *2022 ASEE Annual Conference & Exposition*, (Minneapolis, MN), ASEE Conferences, August 2022.

[6] A. S. Roman, R. Streveler, P. Steif, and L. DiBello, "The Development of a Q Matrix for the Concept Assessment Tool for Statics," in *2010 Annual Conference & Exposition*, (Louisville, Kentucky), ASEE Conferences, June 2010.

[7] P. Steif, "Initial Data from a Statics Concept Inventory," in *2004 Annual Conference*, (Salt Lake City, Utah), ASEE Conferences, June 2004.

[8] P. Steif and M. Hansen, "Comparisons between Performances in a Statics Concept Inventory and Course Examinations," *International Journal of Engineering Education*, vol. 22, no. 5, p. 1070, 2006.

[9] R. Wertz and T. Green, "Best 2019 Zone II Paper: Research to Practice: Leveraging Concept Inventories in Statics Instruction," in *2020 ASEE Virtual Annual Conference Content Access*, (Virtual Online), ASEE Conferences, June 2020.

[10] A. H. Danesh-Yazdi, "Storage and Interaction Diagrams: Extending the Diagrammatic Framework of Kinetic and Free-Body Diagrams to Other Conservation and Accounting Principles," in *2024 ASEE Annual Conference & Exposition*, (Portland, Oregon), ASEE Conferences, June 2024.

[11] F. P. Beer, E. R. Johnston, and D. F. Mazurek, *Vector Mechanics for Engineers: Statics*. New York, NY: McGraw-Hill Education, 9th ed., 2009.

[12] R. C. Hibbeler, *Statics and Mechanics of Materials*. Hoboken, NJ: Pearson, 5th ed., 2017.

[13] W. F. Riley, L. D. Sturges, and D. H. Morris, *Statics and Mechanics of Materials: An Integrated Approach*. New York, NY: J. Wiley, 2nd ed., 2002.

[14] A. H. Danesh-Yazdi, A. Cloutier, and S. Moseley, "Link element design for a Landing-Gear Mechanism in a Statics and Mechanics of Materials Course," in *2024 ASEE Annual Conference & Exposition*, (Portland, Oregon), ASEE Conferences, June 2024.

[15] S. S. Shapiro and M. B. Wilk, "An Analysis of Variance Test for Normality (Complete Samples)," *Biometrika*, vol. 52, no. 3/4, pp. 591–611, 1965.