# Eleven Years of Evidence: Evaluating Problem-Solving Recitations in Statics Instruction

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## Abstract

Statics is a required gateway course for multiple engineering majors at Western Michigan University. Due to the large enrollment and high impact on student progression, improving instructional effectiveness in Statics is a critical priority. Since Spring 2014, a redesigned blended-format Statics section—with two 50-minute lectures and one weekly three-hour problem-solving recitation—has been offered in parallel with the traditional lecture-only format.

This study presents an eleven-year comparative analysis of the two instructional approaches using data from Mechanical and Aerospace Engineering as well as Civil and Construction Engineering students enrolled between Spring 2014 and Fall 2024. Demographic characteristics and incoming cumulative GPA were first compared to assess baseline equivalency between sections. Student performance in Statics, including midterm and final exam scores, was statistically analyzed overall and within GPA-based subgroups. To evaluate long-term impact, student performance in the subsequent Mechanics of Materials course was also examined. Additionally, student and instructor perceptions of the redesigned format were collected to contextualize the quantitative results.

The results show modest but consistent improvements in course grades and passing rates for the redesigned section, while exam performance remains comparable, suggesting that structured problem-solving recitations can enhance overall course success. The findings of this work provide practical and transferable lessons for institutions seeking to enhance engagement and performance in foundational engineering courses through structured, problem-solving–focused recitations.


## Introduction

Statics poses a well-documented challenge for engineering students, as it is often among the first required engineering mechanics courses in the curriculum. Difficulties encountered in Statics are strongly associated with poor performance in subsequent mechanics and design courses, making student success in Statics critical for academic progression and retention. As a result, the need to improve teaching and learning in Statics has been widely recognized over the past several decades.

In response, a variety of instructional approaches have been developed and implemented, many of which emphasize active learning. Among these approaches, flipped-classroom and blended-learning models have gained particular attention. In a flipped classroom, direct instruction is delivered through online videos viewed outside of class, while in-class time is devoted to guided problem solving with instructor support. Blended learning, sometimes referred to as hybrid learning, replaces selected components of traditional face-to-face instruction with structured hands-on activities and/or online learning, while retaining elements of conventional lecturing. Blended learning has become an especially common option in Statics and other core engineering courses [1, 2, 3]. Despite widespread adoption, the effectiveness of flipped and blended instructional models in engineering education remains mixed in the literature. Some studies have reported improved student performance under flipped or blended instruction [4, 5, 6], while others have found no statistically significant differences when compared to traditional lecturing [7, 8, 9]. Faculty perceptions similarly vary; for example, a 2015 survey of 1,089 engineering faculty members found that only 55% reported evidence of improved student learning associated with flipped instruction [10]. These mixed findings suggest that local implementation context, course structure, and instructional design may play a significant role in determining outcomes. While prior studies provide valuable insights, fewer reports examine the long-term outcomes of blended Statics instruction implemented concurrently with a traditional course within the same institutional context. This study contributes to the Statics education literature by examining the long-term outcomes of a blended instructional model implemented alongside a traditional lecture format at a single institution.

At the College of Engineering and Applied Science at Western Michigan University, Statics was taught exclusively using a traditional lecture format prior to 2013. Between Fall 2010 and Fall 2013, course passing rates (defined as percentage of students received C or better) were typically below 60%. The low passing rate in Statics was identified as a contributing factor to reduced second-to-third-year retention within the college. In response, a comprehensive redesign of the Statics course was initiated in 2013, with a pilot implementation launched in Spring 2014.

Starting in Spring 2014, students were given the option to enroll in either a traditional Statics section or one of two redesigned sections. The redesigned course adopted a blended instructional format consisting of two 50-minute lectures and one three-hour problem-solving recitation each week. During lecture sessions, instructors introduced theoretical concepts and demonstrated representative example problems. The recitation sessions were dedicated to structured, scaffolded problem solving, during which students worked collaboratively on four to five carefully sequenced problems. Students were encouraged to discuss solution strategies with peers and seek guidance from the instructor and teaching assistants (TAs) as needed. Each recitation session was led by the lecture instructor, who remained present for the entire meeting. In addition, two TAs supported each session. Importantly, these TAs had previously completed the course under the recitation model and were therefore familiar with its pedagogical structure. In the final 30 minutes of each recitation, students completed an additional problem individually that served as the graded component for the session. Full credit required both correct completion of this problem and demonstrated effort on the preceding collaborative work. Students who did not meaningfully engage in the earlier problems were subject to a grading penalty at the instructor's discretion. This structure fostered sustained instructor–student interaction during collaborative work, and by approximately the fourth week of the semester, the instructor was typically familiar with the majority of students in the course.

This paper extends the authors' prior work [11] by reporting results from an eleven-year longitudinal study of Statics teaching and learning at this institution. To compare student performance in Statics between the traditional and redesigned sections, student data were collected and analyzed for courses offered from Spring 2014 through Fall 2024. Two semesters, Spring 2020 and Fall 2020, impacted by COVID, were excluded from the study due to substantial disruptions to instructional delivery and assessment. To ensure consistency in instructional approach and assessment, only sections taught by two instructors—who jointly led the Statics course redesign—were included in the analysis. Both instructors taught traditional and redesigned sections during the study period. In addition, the analysis was limited to students enrolled in the Mechanical and Aerospace Engineering Department and the Civil and Construction Engineering Department. These criteria resulted in a total sample of 1958 students, of whom 235 were enrolled in the traditional section and 1723 were enrolled in the redesigned section. The traditional lecture-only section was phased out after 2021.

The purpose of the study is to compare student performance in redesigned and traditional Statics sections and to evaluate the impact of the redesigned course on student learning outcomes. Specifically, the study addresses the following research questions:
1. Does student performance differ between the redesigned and traditional Statics sections?
2. Do instructor and student perceptions differ between the two instructional formats?
3. Does student performance in a subsequent mechanics course differ based on the Statics section completed?

**Student demographic and cumulative GPA**

Student demographic characteristics for the two sections are summarized in Tables 1 and 2. The results indicate that the demographic profiles of students enrolled in the traditional and redesigned sections were comparable, suggesting no substantial demographic differences between the two groups.

**Table 1 Enrollment by gender and section**

| Section | Male (%) | Female (%) | Total |
|---|---|---|---|
| Traditional | 200 (85.1%) | 35 (14.9%) | 235 |
| Redesigned | 1451 (84.2%) | 272 (15.8%) | 1723 |

**Table 2 Enrollment by race/ethnicity and section**

| Race/ethnicity | Traditional (%) | Redesigned (%) |
|---|---|---|
| **African American** | 4 (1.7%) | 37 (4.5%) |
| **Asian** | 6 (2.6%) | 49 (2.8%) |
| **Hispanic** | 8 (3.4%) | 105 (6.1%) |
| **International** | 24 (10.2%) | 167 (9.7%) |
| **Two or more** | 8 (3.4%) | 46 (2.7%) |
| **White** | 183 (77.9%) | 1249 (72.5%) |
| **Other/Unknown** | 2 (0.9%) | 30 (1.7%) |

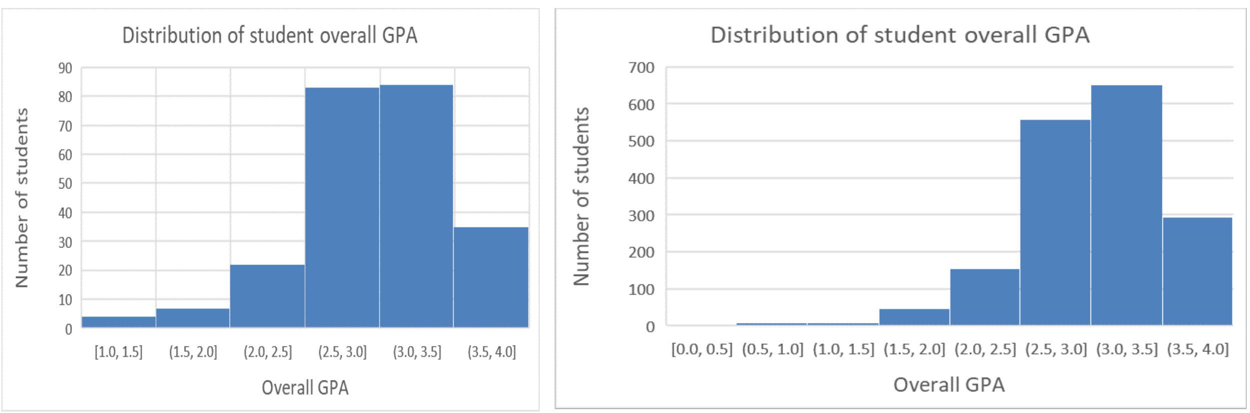
To assess potential differences in students' academic preparation upon entry into Statics, cumulative GPA at the time of course enrollment was compared between the two sections.

Descriptive statistics for cumulative GPA are presented in Table 3. Students in the redesigned section had a slightly higher mean cumulative GPA than those in the traditional section. However, an independent two-sample *t*-test assuming unequal variances was conducted to evaluate whether this difference was statistically significant. The results indicated that the difference in cumulative GPA was not statistically significant at the 95% confidence level ($p$ = 0.109), as the $p$-value exceeded the specified significance level of 0.05.

**Table 3 Comparison of cumulative GPA**

| Section | Mean | Standard deviation |
|---|---|---|
| Traditional | 2.97 | 0.53 |
| Redesigned | 3.02 | 0.53 |

Figure 1 shows the distributions of cumulative GPA for students in the traditional and redesigned sections. The GPA distributions exhibit similar shapes and spread, further supporting the conclusion that the two student groups were academically comparable at the time of enrollment. Together, these results indicate that students in the two sections entered Statics with comparable demographic characteristics and academic preparation.




**(a) Traditional section** **(b) Redesigned section**

**Figure 1: Distribution of student cumulative GPA in the two sections**

**Student performance in Statics**

Table 4 shows the comparison of the passing rate of the traditional section and the redesigned section of Statics. The redesigned section has a moderately higher passing rate compared with traditional section.

**Table 4 Comparison of Statics passing rate**

| Section | Total no. of students | No. of students get C or better | Passing rate |
|---|---|---|---|
| Traditional | 235 | 156 | 66.4% |
| Redesigned | 1723 | 1206 | 70.0% |

The final course grades were converted to numerical scale (A = 4.0, BA = 3.5, B = 3.0, CB = 2.5, C = 2, DC = 1.5, D = 1, E = 0) and compared between the two sections. The result, shown in Table 5, indicates that the redesigned section has higher mean course grade compared to the traditional section.

**Table 5 Comparison of Statics final grade**

| Section | Mean | Standard deviation |
|---|---|---|
| Traditional | 2.13 | 1.17 |
| Redesigned | 2.27 | 1.15 |

An independent two-sample *t*-test of the final grade in numerical scale of the two student sections assuming unequal variances was performed. The results showed that the difference is significant at the 95% confidence level ($p = 0.044$).

The student performance in the midterm exams and final exams is then compared. Typically, the students were given either three or four midterm exams, depending on the instructor and whether it is traditional section or redesigned section. One instructor gives similar midterm exams and final exams to students across different sections and different years, therefore, to exclude the variability to establish the comparison equivalency, only the students taught by the same instructor are compared. Table 6 presents a comparison of midterm exam score, and Table 7 presents a comparison of final exam score. The redesigned section exhibited slightly higher mean midterm and final exam scores than the traditional section; however, independent two-sample *t*-tests indicated that these differences were not statistically significant at the 95% confidence level ($p = 0.071$ for the midterm exam and $p = 0.077$ for the final exam). Although neither difference reached statistical significance, the *p*-values were near the conventional 0.05 threshold, suggesting a consistent positive trend in favor of the redesigned section across both assessments.

**Table 6 Comparison of Midterm Exam Score**

| Section | No. of Midterm Exams | Mean | Standard Deviation |
|---|---|---|---|
| Traditional | 804 | 69.51 | 20.20 |
| Redesigned | 2839 | 70.71 | 21.28 |

**Table 7 Comparison of Final Exam Score**

| Section | No. of Final Exams | Mean | Standard Deviation |
|---|---|---|---|
| Traditional | 217 | 66.14 | 21.40 |
| Redesigned | 868 | 68.44 | 20.75 |

Taken together, the results indicate that students in the redesigned section consistently achieved higher mean performance across multiple measures, including midterm exam scores, final exam scores, overall course grades, and passing rates. Although differences in midterm and final exam scores between the two sections did not reach statistical significance, the redesigned section exhibited higher mean scores on both examinations. These results suggest that the redesigned format may promote more consistent student engagement, increased problem-solving practice, and improved completion of formative assessments throughout the semester. The structured recitation sessions provide sustained opportunities for guided practice and timely feedback, which may enhance cumulative course performance and support improved overall student success, even when performance on high-stakes examinations remains statistically comparable.

**Student performance in a subsequent course**

All of the students from Mechanical and Aerospace Engineering Department, and Civil and Construction Engineering Department are required to take ME2570 – Mechanics of Materials. Since Statics is a prerequisite course of Mechanics of Materials and the two courses are closely related, we use the student performance in Mechanics of Materials to track the differences between the traditional and redesigned Statics sections when they move on to the subsequent courses.

Not all students included in the study subsequently enrolled in Mechanics of Materials. This is likely because some students withdrew from their engineering programs after completing Statics and before taking Mechanics of Materials. Of the 237 students in the traditional Statics section and 1,723 students in the redesigned Statics section included in this study, 177 and 1,245 students, respectively, later completed Mechanics of Materials.

The course grades that students earned in ME 2570 Mechanics of Materials on their first attempt were tracked and analyzed. Table 8 presents a comparison of passing rates in Mechanics of Materials for students who completed either the traditional or redesigned Statics course. The results show that students who completed the redesigned Statics course achieved a higher passing rate in Mechanics of Materials than those who completed the traditional Statics course.

**Table 8 Comparison of Mechanics of Materials passing rate**

| **Section** | **Total no. of students** | **No. of students get C or better in ME2570** | **Passing rate** |
|---|---|---|---|
| Students who took traditional Statics | 177 | 102 | 57.6% |
| Students who took redesigned Statics | 1245 | 788 | 63.3% |

Again, the final course grades of Mechanics of Materials were converted to numerical scale (A = 4.0, BA = 3.5, B = 3.0, CB = 2.5, C = 2, DC = 1.5, D = 1, E = 0) and compared between the two sections. The results are summarized in Table 9. Students who completed the redesigned Statics course achieved a slightly higher mean course grade in Mechanics of Materials than those who completed the traditional Statics course. However, an independent two-sample $t$-test assuming unequal variances indicated that this difference was not statistically significant at the 95% confidence level ($p = 0.157$). Although the difference did not reach statistical significance, the direction of the results remained consistent with earlier findings, again favoring students who completed the redesigned Statics course.

**Table 9 Comparison of Mechanics of Materials final grade**

| Section | Mean | Standard deviation |
|---|---|---|
| Students who took traditional Statics | 1.94 | 1.19 |
| Students who took redesigned Statics | 2.04 | 1.22 |

It should be noted that not all students who enrolled in Statics subsequently completed Mechanics of Materials, and differences in student persistence may partially influence these results.

**Student and instructor perception**

Anonymous student surveys were administered among the redesigned Statics sections near the end of Spring and Fall 2014 semesters, and the Spring 2015 semester. The survey consisted of eighteen statements designed to capture students' perception of the redesigned course, with responses recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). An open-ended section was also included to allow students to provide comments.

Survey results indicated generally positive student perceptions of the redesigned instructional format. Students frequently reported that the redesigned structure allowed them to work through more problems and improved their understanding of course material. Overall, student feedback on the redesigned course was favorable. Table 10 summarizes student responses to Statements 16 and 17 of the survey. More detailed survey results and analyses were reported in the authors' prior work [11].

**Table 10 Student survey responses in the three semesters (Total 211 students)**

| Statements | 5 Strongly agree | 4 Agree | 3 Neutral | 2 Disagree | 1 Strongly disagree | Mean |
|---|---|---|---|---|---|---|
| **16.** I believe that I learned the material better using the new approach than the traditional approach | 97 | 66 | 32 | 11 | 5 | 4.13 |
| **17.** Overall, I like the new approach better than the traditional approach | 95 | 65 | 29 | 14 | 8 | 4.07 |

From the instructors' perspective, the redesigned Statics course led to noticeably higher levels of student engagement compared to the traditional lecture format. Instructors observed that students in the redesigned sections were more actively involved in hands-on learning, particularly during the structured recitation sessions where students worked through problems with immediate support. The increased instructor–student interaction in these sessions also allowed instructors to better understand individual students' learning needs. These positive instructional experiences informed subsequent curricular decisions; beginning in 2021, the department transitioned to offering Statics exclusively in the redesigned format with problem-solving recitations. Building on these observations, one instructor implemented a similar recitation-based structure in Mechanics of Materials beginning in Fall 2022. After several semesters of comparing recitation-based and traditional offerings, improved student performance on exams and final assessments was observed in the recitation format, and student feedback further supported this transition. As a result, all sections of Mechanics of Materials taught by this instructor now adopt a recitation format incorporating key elements of the redesigned Statics course, including weekly modular organization and regular formative feedback. More recently, the same instructor has been teaching Dynamics, a mathematically and conceptually demanding course that requires a strong foundation in mathematics, physics, and Statics and serves as a required course for four different majors. Although still in the planning stage, the instructor is exploring the implementation of a recitation-based format for Dynamics beginning in Fall 2026, extending the instructional approach developed in Statics to additional core mechanics courses.

## Conclusion

To improve the student learning in Statics, faculty in the College of Engineering and Applied Science at Western Michigan University initiated a course redesign that was first implemented in Spring 2014. The central feature of the redesign was a shift from a primarily lecture-based format to a blended structure that reduced traditional lecturing time and incorporated a required weekly problem-solving recitation. During these recitation sessions, students actively worked through Statics problems with guidance and feedback from instructors and TAs.

To evaluate the impact of this redesign, student performance data from Spring 2014 through Fall 2024 were collected and analyzed. The results indicate that students enrolled in the redesigned Statics sections consistently achieved higher mean final course grades and higher passing rates than students in traditional lecture sections. Although differences in high-stakes exam performance, including midterm and final exam scores, did not reach statistical significance, the redesigned sections exhibited higher mean exam scores. These findings suggest that the redesigned format supports improved overall course performance, likely through increased engagement, sustained problem-solving practice, and completion of formative assessments throughout the semester.

Student survey results and instructor perceptions further support the effectiveness of the redesigned course structure. Students reported that the recitation-based format allowed them to work through more problems, receive timely feedback, and develop a stronger understanding of course material. Instructors observed higher levels of student engagement and more frequent instructor–student interaction, enabling earlier identification of learning challenges and more targeted instructional support. Based on these outcomes, the department transitioned to offering Statics exclusively in the redesigned recitation-based format beginning in 2021.

The impact of the redesigned Statics course also extended beyond the course itself. By tracking student performance in a subsequent required mechanics course, Mechanics of Materials, the study found that students who completed redesigned Statics achieved higher passing rates and slightly higher mean course grades than those who completed traditional Statics. Although these downstream differences did not reach statistical significance, the consistent directional advantage suggests that a stronger foundation developed in Statics may support improved persistence and performance in subsequent mechanics coursework.

Overall, the findings from this eleven-year longitudinal study indicate that a recitation-centered instructional model can enhance the student learning experience in Statics without sacrificing academic rigor. Key elements contributing to this improvement include structured weekly recitation sessions, meaningful and timely feedback, clear course organization, and increased opportunities for instructor–student interaction. Given the positive outcomes observed in Statics and the subsequent adoption of similar structures in Mechanics of Materials, this instructional model shows promise for broader application. Future work will examine how specific recitation activities and assessment structures contribute to observed performance differences and will explore the adaptation of recitation-based formats to other high-enrollment, conceptually challenging mechanics courses, such as Dynamics and Thermodynamics.

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