An Analysis of Factors Affecting Student Performance in a Statics Course

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Abstract

At Western Michigan University (WMU) in Kalamazoo, Michigan, the historical passing rate of students in Statics has been low. It is a required course for students across several majors in the College of Engineering and Applied Science. Improving the teaching and learning effectiveness of Statics may have a significant impact on student success and retention by virtue of the large number of students affected. Traditionally Statics has been taught through face-to-face lectures. Since Spring 2014, a redesigned Statics using hybrid flipped course format has been offered parallel to the traditional format.

This study is purposed to analyze the correlations between student performance in Statics and several potential factors, and to evaluate how significantly the redesigned Statics has impacted student learning. Student performance was measured by final exam grade, overall course grade, and score in a Statics concept assessment test. These performance measurements were compared between the traditional and redesigned Statics classes. Additionally, the correlations between several factors, such as student overall GPA and performance in a critical prerequisite course, were statistically analyzed using data from multiple semesters. Preliminary conclusions are drawn based upon the analysis. The university where this study was carried out is a Moderately Selective institution as classified by the Consortium for Student Retention Data Exchange. The lessons learned could be applicable to other institutions with similar student demographics.

Introduction

Statics is a sophomore-level course covering topics including equilibrium of force systems; analysis of trusses, frames and machines; centroid; and moment of inertia of areas, etc. It serves as a prerequisite for several subsequent courses including dynamics, and mechanics of materials. Statics poses special challenge to engineering students because it is often the first engineering science course they take. Moreover, students who have trouble with Statics often perform poorly in subsequent courses.

One of the goals of Statics is to have students learn to solve problems independently, which is a practice-intensive and time-consuming effort for which the traditional face-to-face lecture can provide guidance yet relatively little direct assistance. Students are not able to pause to reflect and understand what is being explained and they may often miss important points in a traditional lecture setting, which is an instructor-centered, relatively passive method of learning. While lecturing still remains an effective and important way of conveying knowledge, it is critical to get students engaged in active learning through activities such as solving problems, working with each other, asking questions and getting feedback.

To enhance student learning in Statics, researchers at various institutions have explored other methods for teaching Statics, such as developing concept map and quantifying students' conceptual understanding[1, 2], developing on-line homework or learning modules[3, 4], peer-led-team-learning[5], project-based learning[6], emporium-based course delivery[7]. Among them, the flipped classroom method[8, 9, 10] has gained popularity. In a flipped classroom, the class time is devoted to guided instruction where students work through problems with the instructor present to provide assistance and answer questions. Lectures are delivered through on-line videos which students are required to watch and learn outside the class time.

In College of Engineering and Applied Science at WMU, Statics is required for students majoring in aerospace engineering, civil engineering, construction engineering, industrial & entrepreneurial engineering, and mechanical engineering. It is a 3-credit-hour course that has been taught in traditional lecturing before 2013. Statics has been traditionally a difficult course in the college as measured by passing rate (the percentage of students getting a C or better). The passing rates and the average course GPA (grade point average) in Statics from Fall 2010 to Fall 2013 ranged from 28% to 78%, mostly below 60%. The low passing rate of Statics negatively impacts the 2nd-to-3rd-year retention rate of the college. Therefore, an effort to redesign Statics took place in 2013 with a pilot redesigned course implemented in spring semester of 2014. The team that engineered the redesign included two faculty members who teach Statics regularly and an Associate dean of Undergraduate Programs and Assessment. Beginning Spring 2014, students are given the options of enrolling in two redesigned Statics sections or a traditional section. The redesigned course took a hybrid flipped course format, which includes traditional face-to-face lecturing, a weekly recitation session during which students solve problems under the guidance of teaching assistants (TAs) and instructors, and online web-based instruction. Typically, during the lecture session, the instructor goes through the topics covered in the week and solves some relatively simple examples. Before the recitation sessions, students are asked to read the relevant textbook sections and watch the related on-line videos to prepare for the recitation session. In the recitation sessions, students solve a set of pre-assigned problems which are due at the end of the recitation sessions. In the recitation sessions, besides problems solving, students often have quizzes, mid-term exams, or the instructor may spend time demonstrating more difficult examples. More details of the course redesign can be found in the authors' previous paper[11].

This paper describes a study addressing two research questions: 1. Does the redesigned hybrid flipped format have a significant impact on student performance in Statics? 2. Are the prerequisite courses and overall GPA good predictors for student performance in Statics? Based on the collected data, preliminary conclusions were drawn to answer the two research questions.

Student Performance

To compare the student performance in Statics between traditional and redesigned classes, data was collected and analyzed for four semesters (spring and Fall 2014, Fall 2015, Fall 2016). In these four semesters, all Statics classes, including traditional and redesigned, were taught by two instructors, who collaboratively led the effort to redesign the course.

A comparison between students' performance in redesigned and traditional Statics courses is shown in Table 1. The grading system for each group is shown in the footnote to Table 1. It is worth noting that the grading system used for the traditional and redesigned classes were slightly different. Also the grading system was slightly adjusted from semester to semester. In the four semesters, all students took the same final exam. The average final exam scores with the corresponding standard deviations in parentheses are shown in the table. The passing rate is calculated as the percentage of students getting a C or better in the course. Table 1 also lists the combined data for all four semesters.

Table 1 Summary of student performance

Semesters	**Group**	**Enrollment**	**Final Exam Score**	**Passing rate**
Spring 2014	Traditional [a]	23	68.1 (18.8)	52.2%
	Redesigned [b]	88	70.8 (17.9)	61.4%
Fall 2014	Traditional [a]	30	65.8 (22.0)	66.7%
	Redesigned [b]	95	65.9 (16.2)	70.5%
Fall 2015	Traditional [c]	50	69.6 (20.2)	64.0%
	Redesigned [d]	94	73.0 (20.6)	78.7%
Fall 2016	Traditional [e]	56	76.7 (12.0)	78.6%
	Redesigned [d]	86	68.2 (16.6)	60.4%
Combined	Traditional	159	71.1 (18.3)	67.9%
	Redesigned	363	69.4 (18.1)	68.0%

[a] Grading system: 5% attendance, 15% quizzes, 10% homework, 51% midterms, 19% final
[b] Grading system: 15% quizzes, 15% recitation, 5% homework, 48% midterms, 17% final
[c] Grading system: 15% quizzes, 11% homework, 54% midterms, 20% final
[d] Grading system: 12% quizzes, 12% recitation, 5% homework, 52% midterms, 19% final
[e] Grading system: 15% quizzes, 10% homework, 51% midterms, 24% final

Data shows the overall performance of the students in the redesigned classes and in the traditional classes was mixed and it varied from semester to semester. In Spring 2014, Fall 2014 and Fall 2015, the students in redesigned classes outperformed students in the traditional class both in final exam score and passing rate; however, in Fall 2016, the students in traditional class outperformed those in redesigned classes both in final exam score and passing rate. The combined data showed that student of the traditional class has a slightly higher score in the final exam than the redesigned classes, but the passing rate of the redesigned classes is slightly higher than the traditional classes.

The statistical T-test of final exam scores of the two student groups assuming unequal variances was performed to see if there is a significant difference between the two groups. The results showed that the difference is insignificant at the 95% confidence level.

Student and instructor perception

Anonymous student surveys were conducted among the redesigned classes near the end of spring and fall semesters of 2014, and spring semester of 2015. The survey contained eighteen statements related to students' perception of the redesigned course, and students answer each question with a scale of 1 (strongly disagree) to 5 (strongly agree). At the end of the survey there was a section for the students to leave comments. The survey results showed that most students liked the redesigned approach. Students expressed that they were able to work more problems and learn the materials better in the redesigned format. Overall the feedback for the redesigned course was quite positive. The detailed information about the survey results was reported in the authors' previous paper[11].

The instructors' perception is that students in the redesigned classes are more engaged in learning than those in the traditional classes. A majority of them are more actively involved in the learning process by solving the problems in the recitation sessions. Also, in the redesigned classes, the instructors know each student better because of the interaction they had with the students in the recitation sessions.

Concept test

A concept test was conducted at the end of fall semester of 2016. The concept test problems were selected from the Concept Inventory for Statics developed by Steif et al [12, 13]. The test consisted of eight multiple choice problems. To eliminate the influence of the teaching style of different instructors, the students were chosen from one traditional class and one redesigned class taught by the same instructor. The mean and deviation of the test score of the two sections are reported in Table 2.

Table 2 Concept test score

Group	Number of students taking the test	Average (%)	Standard deviation (%)
Traditional	48	45.3	18.7
Redesigned	31	40.3	22.5

The results showed that the traditional class outperformed the redesigned class in the concept inventory test, although the statistical T-test of the two student groups assuming unequal variances showed that the difference is insignificant at the 95% confidence level. In this particular semester, the traditional class outperformed the redesigned class in final exam and passing rate also. No conclusion can be drawn about the impact of the teaching format to the conceptual understanding of the subject. More data is required to draw a conclusion.

A possible cause for the low scores in the concept-inventory test by students in both traditional and redesigned courses could be due to the types of statics problems that the students have been asked to practice on in classes and homework. The statics problems are quantitative with numerical calculations, rather than purely conceptual. Unfamiliarity with the format of the concept inventory test could affect student performance. Another cause could be the concept inventory test was conducted towards the end of the semester, when students tend to want to rush through the test and the class period as quickly as possible, without much careful thoughts.

Figure 1 shows the scatterplot of the students' concept test scores versus their Statics course grades. Course grades are 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). Concept test scores are the number of problems the students answered correctly. The plot shows the data points are scattered and the correlation between them is weak. The Pearson correlation coefficient, r is found to be 0.226, indicating relatively weak correlation.

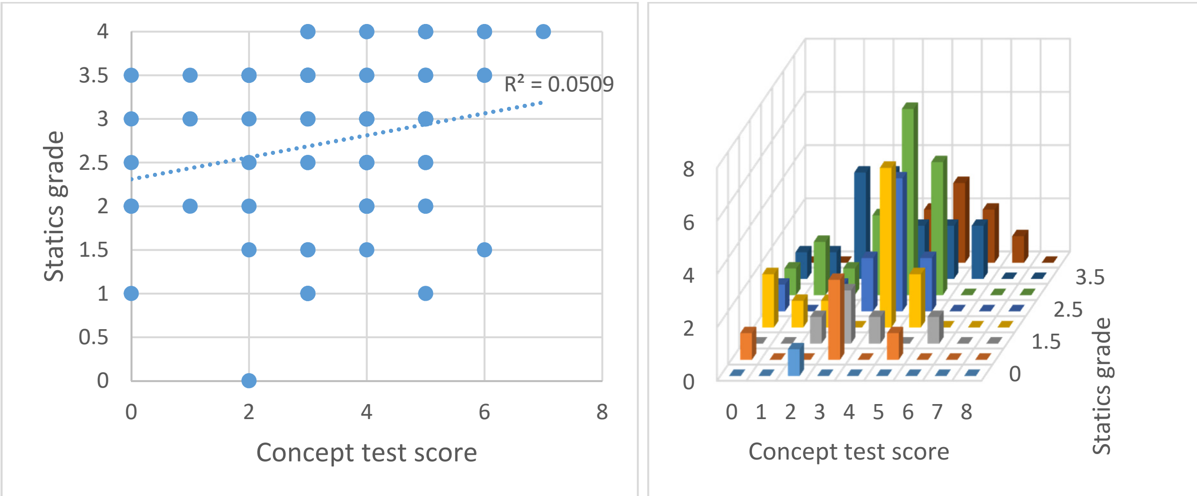

Figure 1 Correlation between concept test score and Statics grade

Correlation to prerequisite course grade

At WMU, Statics is a sophomore-level course for students majoring mechanical and aerospace engineering, and civil and construction engineering. It has two prerequisite courses: MATH 1230 Calculus II or MATH 1710 Calculus II, Science and Engineering, and PHYS 2050/2060 University Physics I and lab. Calculus II is a 4-credit hour math course. In Statics, students are required to frequently use some of the math skills, such as algebra operations, geometry, trigonometric functions, etc. PHYS 2050 University Physics I is the first in a sequence of three physics courses. It is a 4-credit hour course, deals with laws of motion, work and energy. The contents taught in this course, especially in rigid-body mechanics, are similar to Statics. Student performance in these two was analyzed for potential predictors of the student performance in statics.

Statistical analyses were conducted for the students enrolled in all Statics sections in Fall 2016 semester, to examine the correlation, if any, between the two prerequisite courses and Statics grade. Some of the students are transfer students and therefore there is no recorded Math and/or Physics course grade. Table 3 and Table 4 list the basic statistical information showing the prerequisite math and physics course grade, respectively. Prerequisite course grades are converted to the same numerical scale (A = 4.0, BA = 3.5, B = 3.0, CB = 2.5, C = 2, DC = 1.5, D = 1, E = 0). The average math grade of the traditional class actually is slightly lower than the redesigned classes, whereas the average physics grade of the traditional class is slightly higher than the redesigned classes. The statistical T-test of the two student groups assuming unequal variances showed that the difference is insignificant at the 95% confidence level for both courses.

Table 3 Prerequisite math course grade

Group	Number of students	Average	Standard deviation
Traditional	45	2.49	0.92

Redesigned	60	2.53	1.05
Combined	105	2.51	0.99

Table 4 University Physics I course grade

Group	Number of students	Average	Standard deviation
Traditional	43	2.64	0.72
Redesigned	59	2.55	0.88
Combined	105	2.51	0.99

To evaluate the correlation between the student grade in the prerequisite math and physics courses and in Statics**,** scatterplots were generated and are shown in Figure 2 and Figure 3, respectively. The result revealed relatively strong correlations between math and Statics, and between physics and Statics, with the Pearson correlation coefficient, *r* were found to be 0.566 and 0.458, respectively.

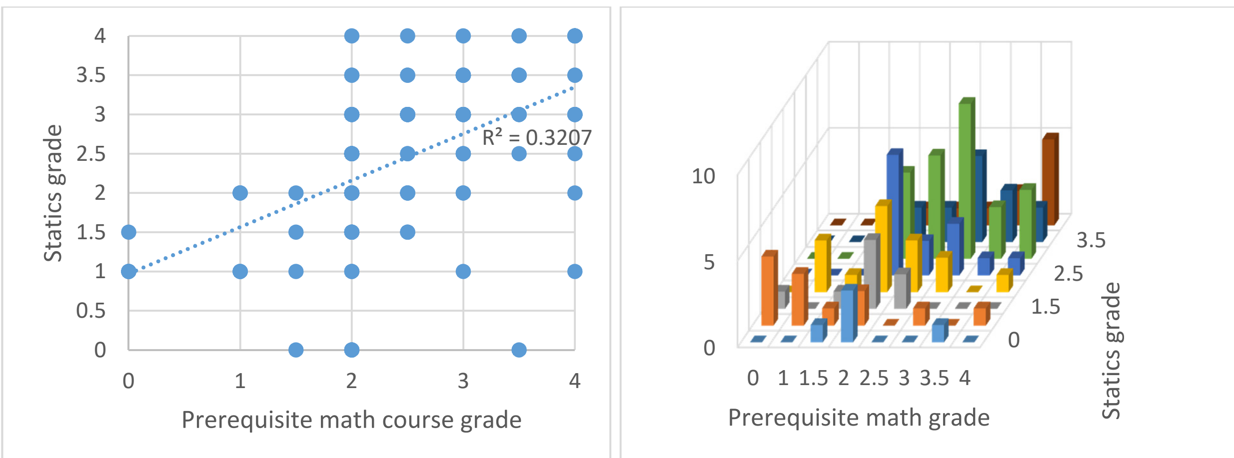

Figure 2 Correlation between prerequisite math course grade and Statics grade

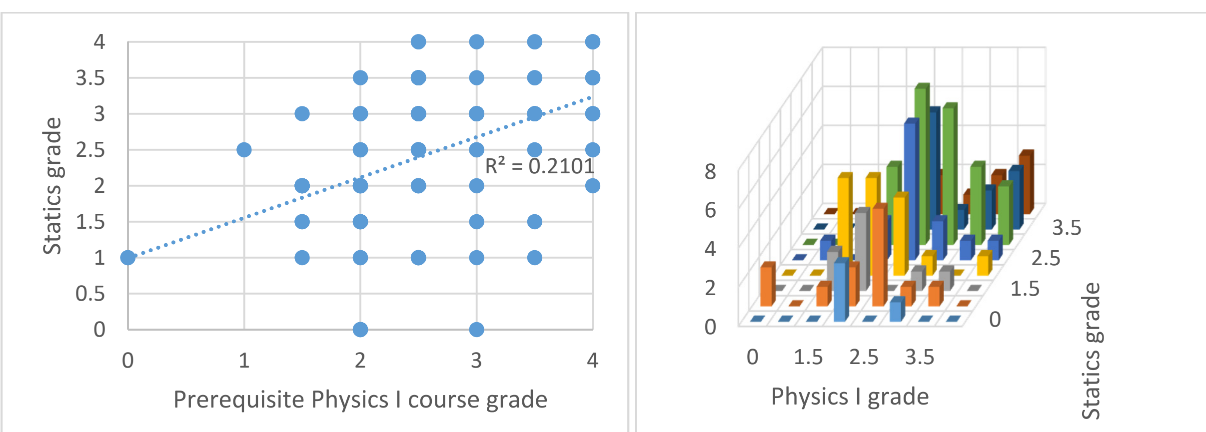

Figure 3 Correlation between prerequisite Physics I grade and Statics grade

Correlation to overall GPA

Next, statistical analyses were conducted to evaluate the correlation between student overall GPA and Statics grade point average, for the students enrolled in all Statics sections in Fall 2016 semester. Table 5 lists the basic statistical information. The average overall GPA of traditional class is a little higher than the redesigned classes, but the statistical T-test of the two student groups assuming unequal variances showed that the difference is insignificant at the 95% confidence level.

Table 5 Overall GPA

Group	Number of students	Average	Standard deviation
Traditional	52	3.04	0.50
Redesigned	84	2.99	0.49
Combined	136	3.01	0.49

A scatterplot is presented in Figure 4. The result revealed a strong correlation between them, with the Pearson correlation coefficient, $r = 0.751$, indicating statistically strong predictive capability of overall GPA on Statics grade.

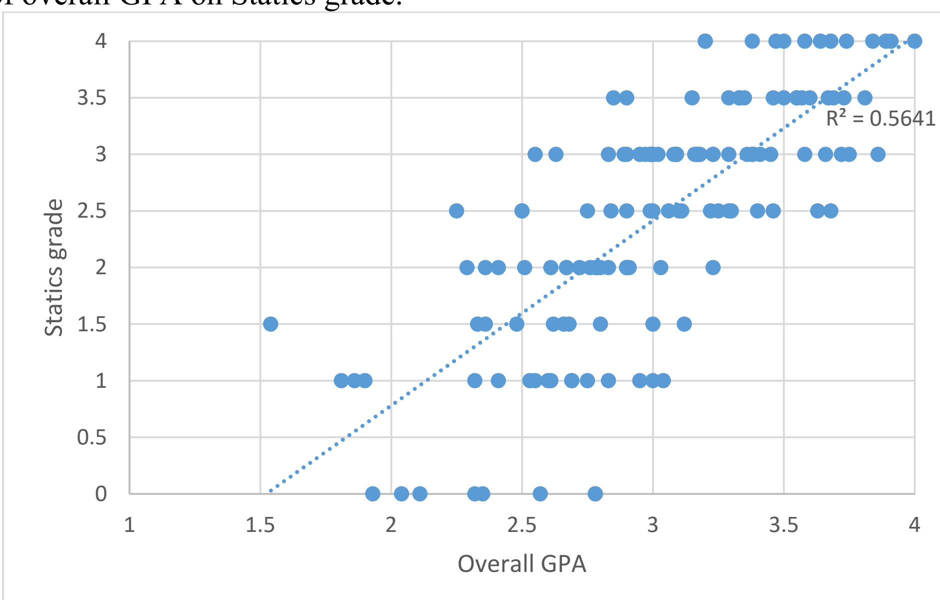

Figure 4 Correlation between overall GPA and Statics grade

Conclusion

To improve student learning in Statics, the faculty in College of Engineering and Applied Science at WMU initiated a course redesign since spring semester of 2014. The major change of the redesigned course format is reducing the traditional lecturing time and adding weekly recitation session, during which students solve problems with the guidance of the instructors and TAs.

The results showed that there is no significant difference between student performance in the traditional versus the redesigned classes as measured by final exam grade and course grade, although the feedback of the students and the perception of the instructors are in favor of the redesigned course format because this format allows more interaction between students with instructor and TAs, and among students.

The difference in Concept Inventory test scores between the students in the traditional class and redesigned class is statistically insignificant, although the students in the traditional class have a higher score than students in the redesigned class.

Other factors, including grade in the prerequisite math and physics courses and overall GPA, were analyzed as potential predicators of performance in Statics. Results showed relative strong correlation between prerequisite math course grade and Statics grade, and strong correlations between overall GPA and Statics GPA. The difference between traditional class and redesigned classes on the prerequisite course grade and overall GPA is statistically insignificant.

This study is based on four semesters' data on student performance in Statics, and only one semester's data on prerequisite math and physics grade point average, and on concept inventory test. A longer study period is needed to make firm conclusion and we intend to continue collecting and analyzing the data. In addition, student performance in the subsequent critical course such as Mechanics of Materials may be collected and analyzed to compare the students' performance between traditional classes and redesigned classes in the future.

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