Evaluation of an Early Exam on Student Performance in Engineering Mechanics: Statics

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Abstract: Engineering Mechanics: Statics is the gateway course between freshman level physics/calculus courses and the Engineering Mechanics series and thus serves a pre-requisite for many upper division courses in most engineering majors. Helping students find success in Statics is paramount to encourage them to build academic confidence that will carry them through their upper division courses and beyond. To help them obtain this success in Statics, we have added an Early Exam during the fourth week of a 16 week semester. This Early Exam is a quarter the length and value of the midterms and final, but is rigorous with a parallel structure to the three other exams. The main goals for the Early Exam are to help students: (1) identify and establish their learning structure for the future study and exams, (2) better understand the course rigor, (3) become familiar with exam policies and format, and (4) identify where they stand in the class. This paper describes the Early Exam in detail and examines the effect of the Early Exam on the midterm exams and overall course grade.

INTRODUCTION

In any endeavor, getting started on the right foot is always important. For university students, the first four weeks are critical to student success [1], [2], [3]. An internal analysis at Colorado State University (CSU) analysis found that if students do not establish proper learning habits and fail to meet academic expectations in the first four weeks, they have a higher probability to score below a D in the course, or even graduate [4]. Faculty at CSU are advised to provide an evaluation before the fourth week of classes to allow students to judge the effectiveness of their study habits. It encourages the students' active involvement in learning and builds a sense of community in the classroom [5]. Remarkably, little work has been done in creating methods to better prepare and engage the students at the beginning of the content delivery learning system. Garfield [6] outlined several principles to help students perform better. For instance, the importance of feedback after testing and identifying and understanding students' conceptual misconceptions.

In the spring of 2018, the instructor of CIVE260 Statics (hereafter Statics) at CSU started to include the Early Exam in the fourth week. This additional assessment provided an ideal opportunity to help students in their adjustment to this gateway course between freshman level physics/calculus and other engineering mechanics courses. We hoped that it would help students reflect on their learning habits at a time when they could still make positive changes. The purpose of this study is to present and evaluate the effect of this Early Exam on student performance in Statics.

METHODS

This paper summarizes the influence of an Early Exam for students enrolled in Statics during the spring 2018 and fall 2018 semesters. Statics students primarily are sophomores but span all academic levels (freshman, sophomore, junior, senior, and/or pre-graduate students). Prerequisites for Statics include taking Calculus I and Physics for Scientists and Engineers I. The course is structured around three 50-minute lectures each week with no labs or recitations. An Early Exam was given during class time in the fourth week out of a 16-week semester. The Early Exams are written with a parallel structure, rigor, and format to the other two midterms and the final but are shorter. Figure 1 provides an example of the Early Exam. They are a quarter length of the three other exams (30 vs 120 minutes). The topics on this exam, as constrained by what has been covered in the first three weeks of Statics, typically include: unit vectors, force components along a line, and the direction cosine angles. Scores from the Early Exam account for 5% of the entire course grade, which allows students to easily recover if they struggle in the Early Exam.

Beyond just looking at the impact of the Early Exam in the semesters it was given, we further contrasted course performance on the Early-Exam semesters (2018) with previous semesters without an Early Exam (academic years 2016-2017). We limited our analysis to this time as Statics has been taught by the same instructor with the same criteria to evaluate student performance.

ARM – In this system:

- Points B, C, and D all lie in the YZ plane.
- A rigid arm AB is supported by two cables, AC and AD.
- The value of force P does not matter in this problem.
- There is a 150 lb magnitude tension force in cable AD.
- The vector components of the tension force in cable AC are $\overrightarrow{T_{AC}} = \langle -200, 66.67, 100 \rangle\ lb$

Find:

A. The vector components of the 150 lb tension force in cable AD pulling on point A [12 pts];

B. The magnitude of tension force $\overrightarrow{T_{AC}}$ which is pulling in the direction of (or parallel to) vector $\overrightarrow{AB}$ [12 pts];

C. The direction cosine angles of vector $\overrightarrow{AD}$? [9 pts]

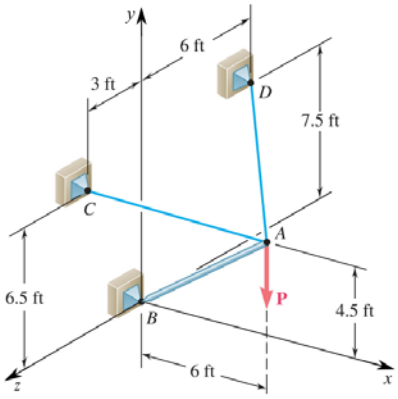

Figure 1. Example of the Early Exam in fall 2018

For statistical analysis, a one-tailed Z-test is used to compare exam performance. The calculated *p*-values are compared to the 0.05 threshold for statistical significance, indicating a 95% confidence interval. A *p*-value less than the threshold indicated statistical significance.

In this study, we specify a threshold score of 70/100 with two reasons: 1) to facilitate the interpretation of results and to meet the CSU graduation requirement of an averaged cumulative GPA of 2.0 (a C average) out of a 4.0 scale; 2) to parallel DFUW rates (proportion of students receiving a grade of D, F, unsatisfactory, or withdrawing from the course). In the following sections, we define 'D/F' performance as that which is below 70/100.

RESULTS AND DISCUSSIONS

Student performance in the Early Exam

The average score for spring and fall 2018 was 75.8/100 and 77.2/100 with relatively large standard deviations of 22.1 and 22.7, respectively (Table 1). Furthermore, 39.6% out of 101 students scored lower than 70/100 in the Early Exam in spring 2018, while 34.5% out of 232 students scored below 70/100 in fall 2018. The D/F rates (<70/100) for both semesters were relatively high which demonstrated that more than one-third of Statics students were not able to demonstrate mastery of the course content early in the semester (Table 1). Students learning a new topic often develop an illusion of material mastery and early assessments help students to formatively correct their conceptual models [7]. Additionally, Woods [8] claimed that many engineering students could not synthesize information from various sources to solve comprehensive problems. Unfortunately, for many students, having the basic knowledge of concept cannot help them solve the problem [9]. A rigorous Early Exam requires students to synthesize and apply concepts to solve a comprehensive problem which offers students a good opportunity to develop a feel of how difficult the course will be.

Table 1: Registration information and Early Exam results of 2018

	Spring 2018	Fall 2018
Registered students	101 students	232 students
Average Early Exam score	75.8/100	77.2/100
Std. Dev.	22.1	22.7
Early Exam Score < 70 (D/F)	40 students (39.6%)	80 students (34.5%)

Effect of Early Exam on the following exams

As the Early Exam is designed in a parallel structure of the following exams (e.g. graded with instructional feedback, returned to the students within a week, and the solution presented in-class), it should provide both instructors and students with the immediate opportunity to correct misconceptions and improve student learning in preparation for the course material and in expectations of the following exams.

Next, we will further analyze how students earning D/F grades on the Early Exam performed on subsequent exams (Table 2). We hypothesized that earning a D/F grade would increase the students' incentive to better prepare for the following exams. This proved to be true with over 60% of students who earned a D/F on the Early Exam improving their performance to score higher than 70/100 on Midterm-1. However, it is also observed from Table 2 that of the students earning a D/F on the Early Exam, the proportion of students who also earned D/F scores on subsequent exams increased as the semester progressed. It is not clear what the direct cause of this is, but we hypothesize that it could be related to students' lack of preparation for this course or an ongoing time management issue [10].

Table 2: Exam performance on later exams for students who scored below 70/100 on Early Exam

Category	2018 Spring (n = 40)			2018 Fall (n = 80)		
	Mid-1	Mid-2	Final	Mid-1	Mid-2	Final
<70 (D/F)	40.0%	40.0%	57.5%	38.8%	55.0%	51.3%
70-80	35.0%	32.5%	25.0%	28.8%	16.3%	32.5%
80-90	15.0%	20.0%	10.0%	18.8%	23.8%	13.8%
90-100	10.0%	7.5%	7.5%	13.8%	5.0%	2.5%

Note: Of the 40 students who scored below 70 in the Early Exam in spring 2018, 40% (16 students) scored D/F on Minterm-1.

Effect of Early Exam on Midterm-1

Combining all student results from both semesters in 2018, the average exam scores increased from the Early Exam (76.8/100) to the Midterm-1 (80.7/100). The standard deviation decreased from 24.2 to 15.4, respectively. This relationship (exams with higher averages having lower standard deviations) is common in Statics. Simply stated, more difficult exams tend to have

greater spread, and easier exams (i.e. higher average score) have less spread. The scores for these two exams are further compared using a one-tailed z-test (p=0.0046), which demonstrates that the average grade for Midterm-1 was significantly better than the Early Exam in 2018.

Subgroups 'A' (students scoring >90 on the Early Exam) and 'D/F' (students scoring <70/100 on the Early Exam) will now be explored to understand how the perceived importance of Early Exam and Midterm-1 success are related. Looking at the aggregate data for spring 2018 (Table 3), for those students who scored lower than 70, we see an average increase of +17.3 points on their Midterm-1 Exam with the average score above 70. Conversely, 'A' Early Exam students generally dropped an average of -13.9 points on the same test. Similar results are seen for 2018 where, Early Exam 'D/F' students had greater progress compared with 'A' students. This result was unexpected but suggests that students who performed well in the Early Exam may have underprepared heading into Midterm-1.

Table 3: Impact of Early Exam on Midterm-1

Semester	**Category**	**Midterm-1 Score**	**Score of (Midterm-1) – (Early Exam)**
Spring 2018	Average value for 'D/F' students (EE < 70)	70.4	+17.3
	Average value for 'A' students (EE > = 90)	83.7	-13.9
Fall 2018	Average value for 'D/F' students (EE < 70)	73.4	+23.1
	Average value for 'A' students (EE > = 90)	86.6	-9.3

Early Exam effect across semesters

This improvement effect of the Early Exam can also be seen when comparing the score distributions of Midterm-1 among the 2016, 2017, and 2018 cohorts. As a reminder 2016 and 2017 did not include the Early Exam in the course routine. Figure 2 below shows the relative frequency of student grades under different grade ranges for three years. As can be seen from Figure 2, students enrolled in 2016 and 2017 had a reasonably similar relative frequency distribution with average scores of 77.9 and 78, respectively, while students enrolled in 2018 had an average score of 80. Furthermore, we use a one-tailed z-test to compare the variances of two groups: 1) students enrolled in 2016 and 2018, which yield a *p*-value of 0.0001; 2) students enrolled in 2017 and 2018, which yield a *p*-value of 0.0012. Thus, we can statistically demonstrate that students who took the Early Exam prior to Midterm-1 in 2018 received significantly higher average scores than those who did not. It should be noted that although the average score difference between courses is less than 3 points, it carries statistical significance and even small differences in grades are important to students. Moreover, engineering colleges hope to see all of their students succeed. This comparison between years strengthens the advantage of having students take the Early Exam.

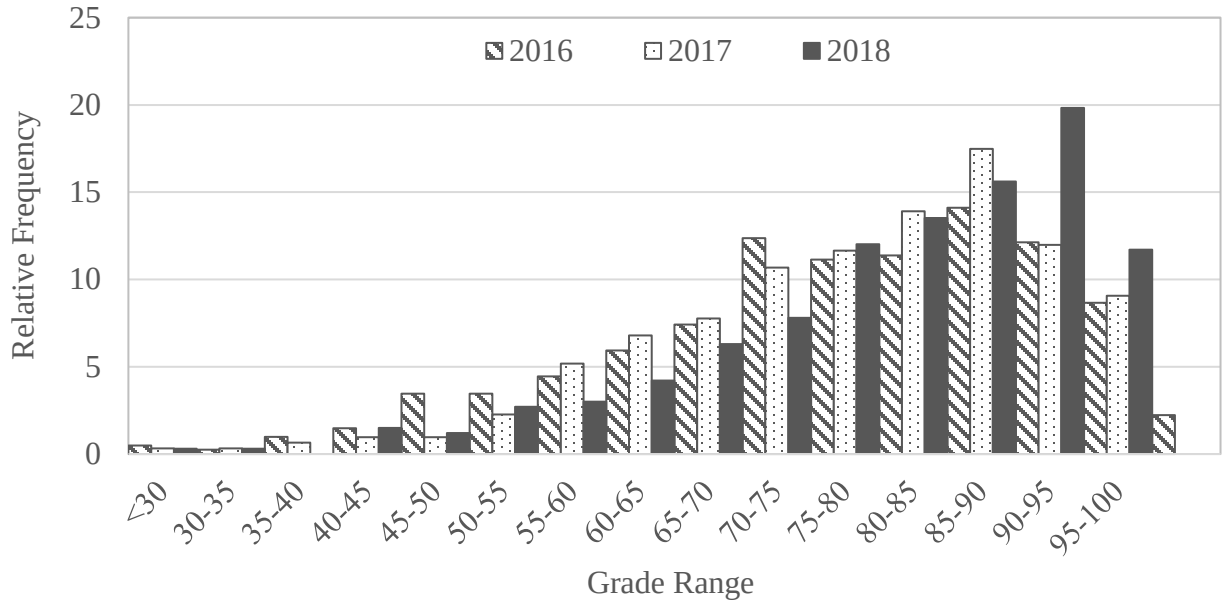

Figure 2: Histograms (non-cumulative, bin size 10) showing the distribution of Midterm-1 scores from all students in each year. Recall that only 2018 included the Early Exam.

CONCLUSIONS AND FUTURE WORK

In this paper, we have made summarized our findings of adding an Early Exam to Statics during the fourth week of 16-week semester and examined its influence on the following three exams at CSU. Our study demonstrated that student performance in the first midterm had been significantly improved after taking an Early Exam. The influence on the entire class may be slim, but it does appear to motivate students scoring <70 on the Early Exam. We also found an apparent contradictory effect on those struggling on the Early Exam (earning D/F scores) and those succeeding (earning A's). This suggests that targeted messaging may need to be developed for the different groups.

Future work related to Early Exams could contain a survey around Midterm-1 to investigate the effect of Early Exam performance on students' study habits. Additionally, it would be interesting to contrast the effects of a single Early Exam versus consistent quizzes throughout the semester. We believe that all educators and institutions should provide students with adequate early assessment mirroring other summative assessments given in a course which allow students to gauge their overall knowledge and adjust their study skills. An Early Exam is one strategy which we have found successful and plan to continue offering in our Statics course.

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