Paper ID #32147

Correlating Mechanics of Materials Student Performance with Scores of a Test over Prerequisite Material

Dr. Nicholas Alan Smith, Wichita State University

Nick Smith is an Assistant Professor of Aerospace Engineering at Wichita State University.

Dr. Roy Y. Myose, Wichita State University

Roy Myose is a Professor of Aerospace Engineering at Wichita State University.

Prof. Syed J Raza, Wichita State University

Retired Air Force Air Vice Marshal. Masters in Aerospace Engineering from Air Force Institute of Technology, Dec 1980. Joined faculty of the department of Aerospace Engineering at Wichita State University in Fall, 2013 as an Engineering Educator. Teaching basic courses in solid mechanics since.

Elizabeth Rollins

Correlating Mechanics of Materials Student Performance with Scores of a Test over Prerequisite Material

Abstract

Background – It can be difficult to differentiate the effects of curriculum and instructional changes from differences in student preparation and capabilities.

Purpose – In this work we will determine whether a test over prerequisite material from Statics and Calculus can be useful in predicting performance in Mechanics of Materials courses.

Method –This "pre-test" involves the application of concepts and knowledge through problem solving rather than multiple-choice questions alone. This pre-test was administered to 692 students in 19 sections taught by three different instructors over four years at Wichita State University.

Conclusions – Results show that pre-test scores given at the beginning of the semester correlate reasonably well with the semester grade point where the Pearson correlation coefficient was +0.52. Students who earned a semester grade of an A averaged 87.9% on the pre-test, B students averaged 79.7% on the pre-test, C students averaged 71.2% on the pre-test, D students averaged 65.5% and students who failed or withdrew averaged 54.9%.

Background

Educators in general strive to adapt and improve their techniques to best suit the needs of their students. Today's students are, in most cases, from a different age and generation than their instructors, which requires different techniques (Barreiro & Bozutti, 2017). Universities are also placing much greater emphasis on reaching out to underserved populations and doing so effectively also requires adapting teaching methods (Winkelmes et al., 2016). One challenge when adapting instructional techniques is differentiating the efficacy of the changed technique from student capabilities and preparation. Positive changes could be masked by a group of underprepared students or negative changes could be artificially buoyed by a group of super students.

The COVID-19 pandemic has also necessitated many instructional changes. Some of these changes may be temporary, while others are longer-term. In addition to instructional changes, students' needs and even the composition of classes will certainly be altered at least temporarily. Once again it becomes important to understand the effect of instructional changes and to differentiate those from changes in the students.

After successful implementation of a prerequisite test in Engineering Statics courses at Wichita State University (Myose et al., 2019), a similar test over prerequisite statics and calculus material has been implemented for Mechanics of Materials classes. In this work the authors will correlate end of the semester performance with pre-test scores to be used as a baseline for future studies on the effects of instructional change.

A number of different studies have reported incorporating concept inventory tests in varying engineering subjects (Papadopoulos, 2008) including Mechanics of Materials (Sweeney et al., 2007). However, the focus of these multiple-choice type concept inventory tests is to measure students' understanding of a mechanics topic after it has been taught. Indeed, in the Statics Concept Inventory (SCI) test, Steif & Hansen (2007) note that "the SCI offers neglible information as a pre-test." In comparison, the focus of the pre-test given at Wichita State is different and somewhat unique in that it is a test over pre-requisite material given at the beginning of the semester which is then correlated with the end of semester grade.

Test for Prerequisite Knowledge and Skills Associated with Mechanics of Materials

The Mechanics of Materials pre-test developed at Wichita State consists of five problems over material covered in the prerequisite Statics and Calculus courses. The chosen problems, they have direct applications to Engineering Mechanics, and are in a simpler basic form. The topical areas covered by the six problems are: (1) polynomial integration, (2) moment (torque) calculation, (3) equilibrium, (4) distributed loading, and (5) moments of inertia. Many of the problems involve multiple parts where the answer for part (b) depends on the answer from part (a). The exceptions are those for polynomial integration which have two independent parts (i.e., effectively two separate questions "rolled" into one). These questions are posed in multiple-choice format with some wrong "answers" that could be part-way to the final correct answer or are the answer to a different version of the pre-test.

In order to allow comparison from semester to semester as well as from instructor to instructor, the problems in the pre-test were essentially the same from one administration of the pre-test to the next. The main difference was a change in the given values to the problems (e.g., magnitude or angle) and order of the answers in multiple-choice questions. Additional details about the pre-test problems are unfortunately not included in the paper. The reason is to prevent students from obtaining too much information which can change the results in future administration of the pre-test.

Each Mechanics of Materials instructor used a standard process for the pre-test. Students were informed about what topical areas were involved (i.e., the list of five topics discussed earlier). The pre-test was given one week after the start of the semester, without any direct review of the prerequisite Statics and Calculus material. Students were asked to bring a scientific calculator with the ability to perform calculations involving trigonometric functions. The pre-test was closed book, closed notes, without the use of self-generated crib sheets. However, an equation sheet consisting of a copy of the inside front cover of the Statics textbook (Hibbeler's *Engineering Mechanics: Statics*) was provided. Students were cautioned that the notation used in the Statics textbook may differ from what they may be accustomed to, and the equation sheet was provided in advance to allow students to become familiar with the notation. Irrespective of the amount of class time available, students were given a fixed length of 50 minutes maximum to take the pre-test. It should be noted that roughly half of the students were finished in about 30 minutes during any given administration of the pre-test. All exams were graded using the same key to ensure a consistent grading process and methodology. Although students were informed about their overall score in the pre-test and the subscores in each topical area, the graded tests were not returned nor were students allowed to view them again. The only minor variation from instructor to instructor was the course grade value assigned for the pre-test which ranged from 3% to 5% of the semester grade.

Results and Analysis

Table 1 presents the results correlating average pre-test score against semester grades in major groupings of A, B, C, D, and F as well as W for withdrawal. The results are for 692 students in 19 sections of Mechanics of Materials from fall 2015 through fall 2019, with some caveats. Although 692 students took the pre-test, only 667 students ultimately received letter grades while the remaining 25 students withdrew from the course by the 10th week of classes. It should also be noted that there are a few students who show up more than once due to repeating the course in a subsequent semester. Wichita State has a 12-point grading scale with + or – discriminators in A through D grades, except that an A+ is not given. The letter grades correspond to the following grade points: A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, B- = 2.7, C+ = 2.3, C = 2.0, C- = 1.7, D+ = 1.3, D = 1.0, D- = 0.7, and F = 0.0. No grade points are given for withdrawal (i.e., a "W" grade is not part of the grade point average calculation). Figure 1 presents the results for the same 692 students, but with + or – discriminators included in the grade, the number of students at each grade level is indicated between parentheses.

Table 1. Average pre-test score for each major grade category.

End of semester grade	A's	B's	C's	D's	F's	W's
Average pre-test score	87.9%	79.7%	71.2%	65.5%	54.4%	55.9%
Number of students	147	195	201	70	54	25

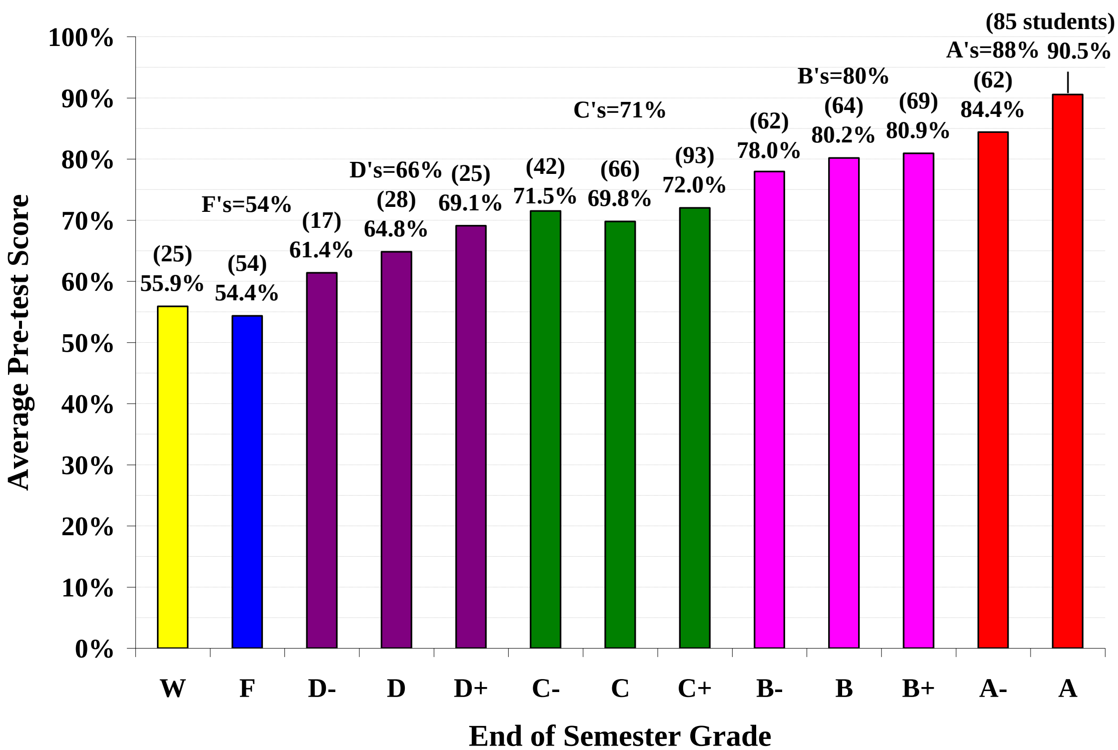

Figure 1. Semester grade as a function of average pre-test score.

Results show that students who earned an A achieved a pre-test score on average of ~88%, B students had ~80%, C students had ~71%, D students had ~66%, F students had ~54%, and those who withdrew had ~56%. This suggests that students with pre-test scores below 71% were in danger of not passing the course, and instructors warned such students in the second week of the semester to obtain tutoring or other support.

In order to determine how well correlated the pre-test scores were to semester grades, the Pearson correlation coefficient was determined for the data. In the present study, the grades were converted to grade points (A = 4.0, A- = 3.7, etc.) and then correlated with the pre-test scores. The analysis shows that pre-test scores and grade point correlate reasonably well with a Pearson correlation coefficient of +0.52. A Pearson correlation coefficient of -1 would be anti-correlation (i.e, low pre-test scores correlate with high grade points) while a coefficient of 0 would indicate no correlation at all and a coefficient of +1 would indicate perfect correlation. Low correlation coefficients indicate a lot of scatter and variation while correlation coefficient approaching one indicates very little scatter and variation in the results. The data used to fit the Pearson correlation coefficient are shown in Figure 2. Each datapoint represents the average

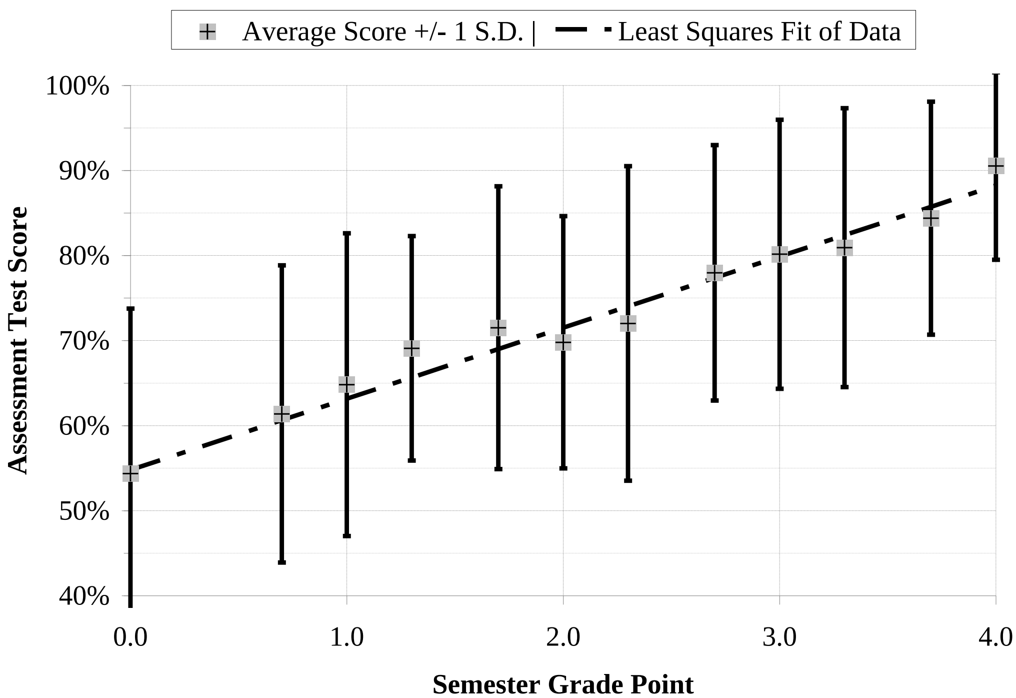

Figure 2. Pre-test scores as a function of end of semester grades.

pre-test score (plus or minus one standard deviation) for each grade (converted to grade points).

The results shown in Figure 1 and Table 1 relate to averages for the entire 692 students from fall 2015 through fall 2019. The discussion up to this point has focused on course-wide correlation of pre-test scores with end-of-semester grades involving large datasets of students. However, individual performance does not necessarily follow the behavior of the entire class. This is illustrated in Figure 3, which shows the distribution of pre-test scores for each whole letter grade. From the graph, it can be seen that approximately 5% of the students who did not pass the course (with semester grades of D’s or F’s) scored in the 90s on the pre-test. If the pre-test score was a precise predictor of individual performance, then these students should have passed the course (with an A!). Conversely, approximately 14% of the students who passed the course scored below 60 on the pre-test. These students may have been capable students who did not take the pre-test seriously because of the low (3-5%) semester grade weight of the pre-test. Another possibility is that they had weak prerequisite knowledge but put significant effort to learn the material during the course. The varying distributions of pre-test scores for students who passed, all students, and those who did not pass in Figure 3 suggest that the pre-test may not necessarily be a good predictor of individual performance. However, the overall results suggest that the pre-test is a reasonably good indicator of class-wide student capability and prerequisite knowledge level, provided that the number of students is large enough (100+) to be statistically meaningful. Since the pre-test is given at the beginning of the semester to predict end-of-semester performance, the pre-test would be a useful tool for an instructor to use to measure the effect of changes in teaching format, examination structure, or active intervention for student success.

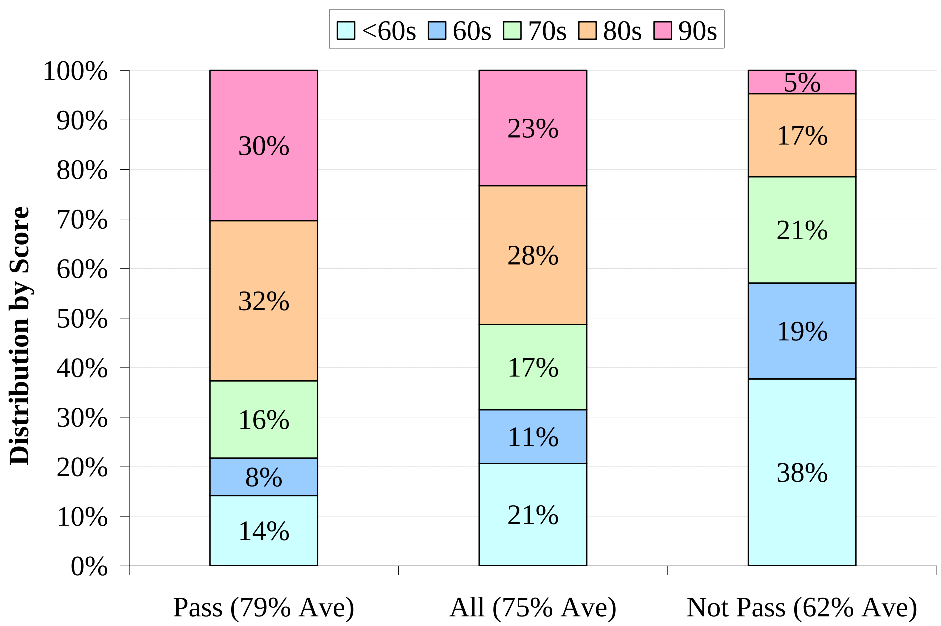

Figure 3. Pre-test score distribution by end of semester category: pass, all (everyone), & not pass.

To better understand which areas might need the most review, student performance for each topic is broken down in Figure 4. In this we see that the “theoretical” problems based purely in mathematics appears to pose the least difficulty, problems related to force equilibrium pose some difficulty and the moment of inertia is the most troublesome problem on the pre-test. Students having difficulty relating theoretical concepts to the practical concepts is a common issue with generation Z students (Barreiro & Bozutti, 2017). This indicates a great need for review of the more practically oriented engineering topics. While it could also indicate a problem in Statics instruction, many students take Statics elsewhere and transfer the credit, which is problematic for enforcing any form of standardized curriculum. An investigation into

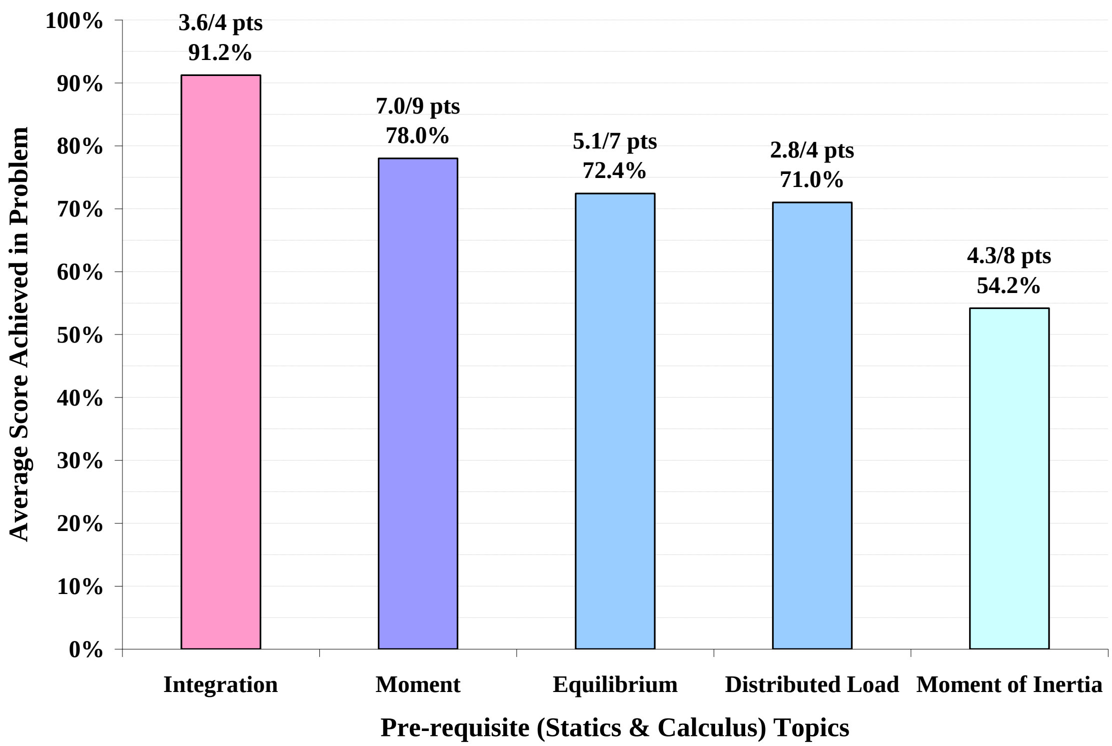

Figure 4. Average score in each pre-test topical area.

whether students with transferred Statics credit have greater difficulty with certain problems on the pre-test could be considered in a future study.

Summary

A prerequisite test given at the beginning of the semester in Mechanics of Materials at Wichita State has been used since 2015 to gauge incoming student capability and prerequisite knowledge. This pre-test was shown to be correlate moderately well with the class end-of-semester grade even though the pre-test is given before any substantive teaching of new material occurs. Therefore, the pre-test is a good tool to use as a course-level control metric whenever changes to the course are attempted. It should be noted, however, that individual course performance is not as well predicted by the pre-test.

In other work the pre-test discussed in this paper has been used to evaluate mid-semester course changes necessitated by the COVID19 Pandemic (Myose & Rollins, 2020). In yet another study, Myose et al. found that mandatory attendance of the face-to-face portion of a hybrid Mechanics of Materials course resulted in significant grade and pass rate improvement for students with similar pre-test scores (Myose et al., 2020).

Future work under consideration includes studies on transfer students' preparation in prerequisite knowledge and studies of other variables such as class size on student performance while controlling for the capability and prerequisite knowledge level of the incoming students. Another avenue of future work is to examine if a possible correlation between student capability and prerequisite knowledge versus course outcomes performance exists. This was not done in the present paper due to the current transition from ABET accreditation criteria a-k to a slightly different set of criteria 1-7.

Bibliography

Barreiro, S. C., & Bozutti, D. F. (2017). Challenges and Difficulties to Teaching Engineering to Generation Z: a case research. *Propósitos y Representaciones*, *5*(2), 127–183.

Myose, R., Kok, F. N., & Rollins, E. (2020). A Hybrid Mechanics of Materials Course Part 1: Evolution of the Course to Improve Student Performance and Retention. *ASEE North Midwest Section Annual Conference*, 11.

Myose, R., Raza, S., Rollins, E., Buerge, B., & Smith, N. (2019). Prerequisite Testing as a Tool to Gauge Incoming Student Capability and Knowledge in an Engineering Statics Course. *Proceedings of the 2019 Midwest Section Conference of the American Society for Engineering Education*.

Myose, R., & Rollins, E. (2020). A Hybrid Mechanics of Materials Course Part 2: Study of the Effect of a Sudden Change to Fully-Online Format. *ASEE North Midwest Section Annual Conference*.

Papadopoulos, C. (2008). Assessing Cognitive Reasoning And Learning In Mechanics. *2008 Annual Conference & Exposition Proceedings*, 13.226.1-13.226.18. https://doi.org/10.18260/1-2--4347

Steif, P. S., & Hansen, M. A. (2007). New Practices for Administering and Analyzing the Results of Concept Inventories. *Journal of Engineering Education*, *96*(3), 205–212. https://doi.org/10.1002/j.2168-9830.2007.tb00930.x

Sweeney, S., Englund, R., & Edwards, R. (2007). Direct Assessment Of Mechanics Of Materials Learning With Concept Inventory. *2007 Annual Conference & Exposition Proceedings*, 12.549.1-12.549.10. https://doi.org/10.18260/1-2--1789

Winkelmes, M.-A., Bernacki, M., Butler, J., Zochowski, M., Golanics, J., & Weavil, K. H. (2016). A teaching intervention that increases underserved college students' success. *Peer Review*, *18*(1/2), 31–36.