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Does Congruency Between Homework and Test Problems Improve Test Performance?

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The purpose of this study was to understand whether the alignment of homework problems with test problems, in terms of their complexity and difficulty, can improve test performance. A post course study was conducted examining the correlation between individual student scores on online homework and on subsequent, associated tests. Data from two sections of an undergraduate statics course taught by the author at Cleveland State University during the fall 2022 and spring 2023 semesters were examined. The course content, lecture notes, in-class examples, textbook, and online learning platforms remained the same, and the test questions were similar. All homework was completed through the textbook publisher's online learning platform. The problems for the assigned homework were different. Overall, the level of difficulty and expected time needed to complete the spring semester problems were approximately 25% greater than that for the fall semester and better aligned with the test problems. It was expected that congruency between homework and test problems would result in better test grades.

Correlation analyses indicated that the relationship between the performance on the homework and the final grades in the course were stronger for the spring semester (0.877) than for the fall semester (0.712). For each of the seven summative tests and associated homework assignments, the relationship between the scores were examined. For fall semester, the correlations were in the range [0.18-0.58], whereas for the spring semester they were in the range [0.47-0.69]. However, descriptive statistics of the homework scores and test scores, suggested that the 35 students during the fall 2022 semester generally performed better than the 38 students during the spring 2023 semester on both the assigned homework and tests. That observation was confirmed through a series of comparison of means tests, which compared the performance on both the homework and tests across the two semesters. Therefore, assigning homework questions that better aligned with the test questions, albeit more difficult, appeared to strengthen the association between homework grades and test grades but did not translate to better test grades.

Introduction

For the 2021 -2022 and 2022-2023 academic years, I was assigned to teach ESC 201 Statics at Cleveland State University. It is a core course in both the Civil Engineering and Mechanical Engineering programs and it is often the first engineering course students in these programs experience, apart from an introduction to engineering design course. The content of the course includes many topics and assumes a background in geometry, algebra, calculus and physics. Admittedly, this course is the source of much angst for both students and instructors. I was told to expect students to be unhappy with the amount of work the course entails and that they would complain. I was also told to expect a relatively high DFW rate (percent of students earning D and F grades or withdrawing from the course) and a relatively low teaching evaluation.

The first year went as expected. Most of my preparation had been spent relearning the material, as I hadn't studied statics in well over twenty years. That meant I ended up relying on the

prepared PowerPoint decks provided by the publisher. I did deviate from the historical two midterms and final exam structure of the course, opting for six small tests each worth 10% and a seventh final test worth 20%. The students benefitted from the removal of the high-stakes exams, but they also benefitted from the opportunity that I had to fine tune my expectations about the number of problems students could complete during a 50-minute test. Students were assigned weekly pencil and paper homework problems, which were uploaded to BlackBoard and graded by a graduate teaching assistant. A full point was given for a complete answer and half a point was given for a partial answer, so long as it appeared to be a reasonable attempt at a solution. The solutions to the homework problems were reviewed in class, prior to the associated test. The Washkewicz College of Engineering had instituted a recitation program, and it included optional weekly recitation sessions dedicated to statics. Although students were encouraged to attend, attendance remained very low both semesters.

The second year went much better. Instead of PowerPoint presentations, class time was spent writing notes and working problems on the white board, often with some form of a visual aid or prop. The 6+1 test structure was retained but retakes were offered for each of the 6, 10% tests, resulting in an overall increase in final grade [1]. Instead of pencil and paper homework, homework was completed online using Pearson Mastering. The recitation sessions became mandatory and the peer teachers for statics were directed to help students work homework problems in Pearson Mastering.

Pearson Mastering provides instructors access to all of the problems in the current and some previous versions of the textbook. For those not familiar with the Pearson textbook Engineering Mechanics: Statics [2], each chapter includes three different types of problems: fundamental, exercise, and review problems. The fundamental and review problems tend to be focused on one or two interrelated concepts and partial solutions are provided in the back of the textbook. The exercise problems range in complexity and only the final answers are provided, except those for every fourth question. The questions without answers are indicated in the textbook by an asterisk.

For the fall 2022 semester, using the 15th edition of the textbook, the homework was made up of problem sets of asterisk indicated problems, while the test problems were drawn from the available fundamental and review problems. The student feedback was that the asterisk problems were sometimes too difficult and did not align with test problems. For the spring 2023 semester, the homework was changed to mostly fundamental and review problems, to be consistent with the problems students would see on the tests. The primary hypothesis was that practicing similarly complex or difficult problems would result in similar performance on the homework and the tests. In other words, the correlation between performance on the homework and on the tests would be stronger when both were made up of similar fundamental and review problems. Given the student feedback, the secondary hypothesis was that the shift to the fundamental and review problems for the homework would improve performance on both the homework and the tests. The foundational premise for these hypotheses is that graded homework is positively related to academic performance.

Literature review

There is ample evidence that graded homework is positively correlated with midterm and/or final exam scores. A few examples from the current millennia are provided for illustration. Latif and Miles [3] compared the performance on the final exam across three sections of the same introductory course, where one section received graded homework, the other received quizzes, and the third received neither. They found that homework positively impacted the final exam scores. This result was expected, as they had previously found graded homework to improve academic performance in an economics course [4]. Grodner and Rupp [5] also found homework in a macroeconomics course was beneficial to student learning, especially for those who initially performed poorly. Eren and Henderson [6] found extra homework improved test scores, and that the impact was greater for high and low achievers.

However, the positive effect of homework on academic performance has not always been observed. For two semesters, Trussel and Dietz [7] compared the test scores between concurrent sections of the same preparatory math course taken by electrical and computer engineering students. Each semester, all students were assigned homework but the homework was only graded for one of the two sections. The positive effect of graded homework on test scores was found to be significant during only one of the two semesters. Fernandez et al. [8] examined the scores on homework, quizzes, tests and exams in four undergraduate engineering courses. Correlations involving homework scores were in the range of [0.23, 0.57] indicating a moderate strength of relationship, at best. In multiple regression models describing the final exam scores in terms of the other scores, homework was not found to be a significant factor.

In the current study, it was assumed that homework matters, that homework has a positive impact on test performance. The first hypothesis was focused on testing whether consistency of the homework and test problems would lead to a stronger correlation between students' performance on homework and tests. The second hypothesis was focused on whether the shift to using fundamental and review problems for both the homework and tests would translate to better test grades.

Based on the student feedback about the difficulty of the asterisked problems used for homework during the fall 2022 semester, it was believed that the shift to using fundamental and review problems meant that the homework would be easier. In Pearson Mastering, data is gathered on the difficulty and time taken for each problem. It turned out that the problem sets made up of fundamental and practice problems were generally more difficult than the problems sets made up of the asterisk indicated problems. Therefore, the secondary hypothesis is testing whether more difficult homework improves test performance.

Methodology

Institutional Review Board approval (IRB-FY-2023-99) was obtained to access the de-identified grade books from BlackBoard and Pearson Mastering for the fall 2022 and spring 2023 sections

of ESC 201 Statics for the purposes of conducting a post course analysis of homework and test grades.

The approval did not extend to other data sources. Access to student grade point averages, grades in prerequisite courses, whether or not the course was being repeated, or any characteristic of the students had not been approved and therefore such data were not available. Such data would be needed to test for differences between the 35 students registered in the fall 2022 semester and the 38 students registered in the spring 2023 semester.

The data from the fall 2022 semester represented students who received incongruous homework and test questions, whereas the data from the spring 2023 semester represented students who received homework and test questions that were congruent. Congruency was based on the whether the problems were identified as fundamental, exercise or review problems. The fall 2022 group received exercise problems for homework and fundamental and review problems on tests. The spring 2023 group received fundamental and review problems for both homework and on tests. The level of difficulty of the homework problems was included in the data set from Pearson Mastering.

To test the primary hypothesis, whether the relationship between the performance on homework and tests would be stronger when the homework and test questions were similar, a correlation analysis was conducted. Additionally, a linear regression analysis was conducted to test the relationship between the performance on the homework and the performance on the tests.

To test the secondary hypothesis, whether a stronger relationship between homework performance and test performance would translate to better test grades, two-sample comparison of means tests were conducted for each of the seven tests, comparing the test performance between the fall 2022 and spring 2023 semesters.

Results

For each semester, the Pearson Mastering dataset included details about the difficulty rating and time to completion for individual homework questions. The difficulty rating is given on a scale of 1 to 4 with 1 being the least difficult and 4 being the most difficult. These data were aggregated by chapter and the averages are presented on Table 1 for each semester.

The motivation to change the homework problems was to gain better consistency between the types of problems practiced for homework and the problems on the tests. In so doing, the average difficulty of the problems increased for Chapters 2, 4, 5, and 8 but decreased for Chapters 3, 6 and 9. On average, the time per question increased for Chapters 4, 8, and 10 but decreased for Chapters 2, 3, 6, and 9. Generally speaking, more difficult problems took more time. Overall, the difficulty and average time to complete questions increased and the total number of questions increased from 94 to 109.

Table 1. Average Difficulty and Average Time of Homework

	Fall 2022			Spring 2023		
Chapter	Difficulty	Time per question, min	Number of questions	Difficulty	Time per question, min	Number of questions
2	1.8	8.6	15	2.0	8.0	20
3	1.3	9.1	7	1.1	7.4	7
4	1.7	7.8	22	2.4	8.2	27
5	1.7	10.0	7	2.2	10.0	13
6	2.1	13.0	9	1.9	9.2	11
8	2.4	8.0	9	2.6	12.0	10
9	1.7	6.1	11	1.1	5.9	10
10	2.0	5.9	14	2.0	9.6	11

The Pearson Mastering dataset also included the scores for each problem for each student. These data were aggregated for each chapter and are represented as a percentage on Table 2. The BlackBoard grade book included the scores on each test for each student. These data were aggregated and are also shown as percentages on Table 2. Note that Chapter 1 was a review chapter and did not have an associated test, therefore the Chapter 1 homework results were not included in the analysis. Chapter 7 was not covered in the course. Both the homework scores and test scores for the fall 2022 semester appear to be better than those of the spring 2023 semester.

Table 2. Descriptive Statistics of Fall 2022 and Spring 2023 Homework and Test Grades

	Fall 2022				Spring 2023			
	Homework		Test		Homework		Test	
Chapter	Mean	St dev	Mean	St dev	Mean	St dev	Mean	St dev
2	81.3	22.1	82.6	18.0	79.2	23.3	77.9	17.2
3	90.2	19.4	86.8	15.5	86.2	25.9	84.0	16.2
4	86.8	16.8	86.1	16.2	77.0	24.4	72.5	16.2
5	86.7	18.7	75.5	21.7	79.4	19.7	74.7	20.2
6	75.0	24.0	86.1	18.5	85.1	20.5	77.4	20.3
8	78.4	23.8	78.6	17.2	63.6	29.1	70.9	22.8
9&10	72.5	32.4	82.4	19.3	68.5	28.9	67.1	27.0

The homework scores were aggregated by chapter for each student and plotted against their test scores. The homework scores for Chapters 9 and 10 were taken together because they map to a single test. The plots for the fall 2022 and spring 2023 semesters are shown on Figures 1 and 2 respectively. The plots indicate that there were students each semester who achieved perfect or near perfect scores on the homework, and students who either did very poorly on the homework or chose not to complete it. They also show that there were students who achieved perfect or near perfect scores on the tests. Otherwise, the distribution of scores appear similar to that published by Fernandez et al. [8].

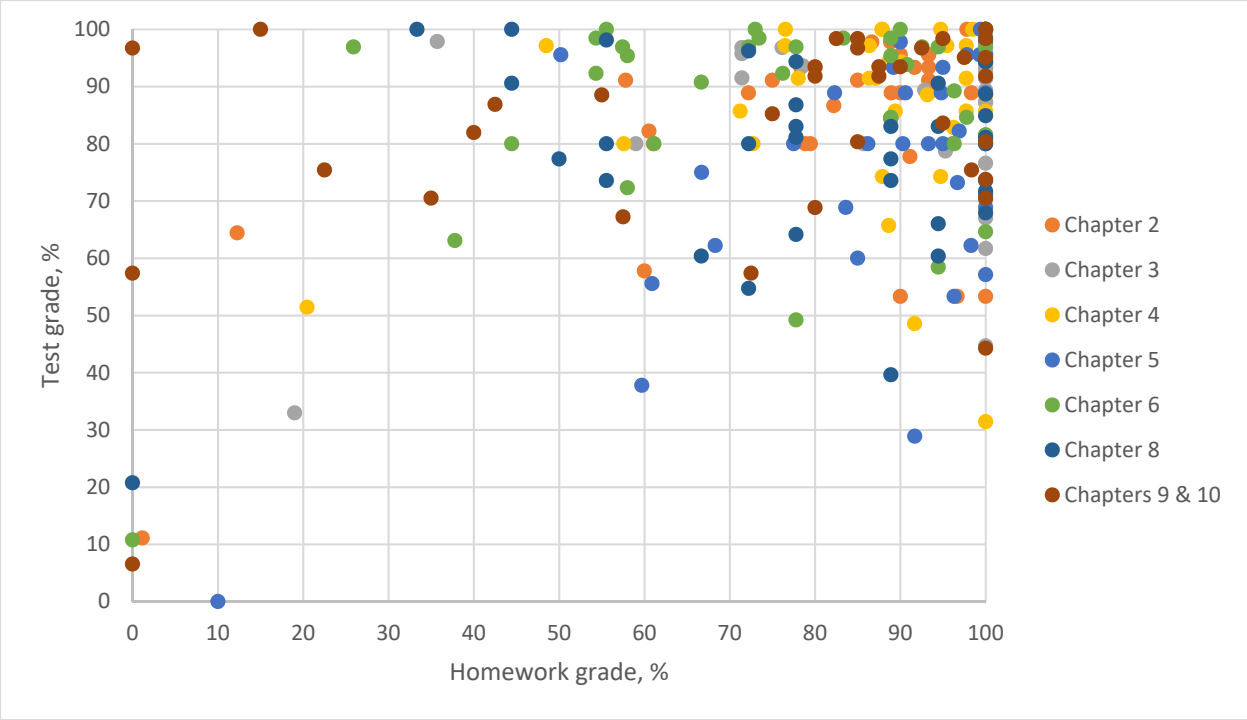

Figure 1. Fall 2022 homework and test grades

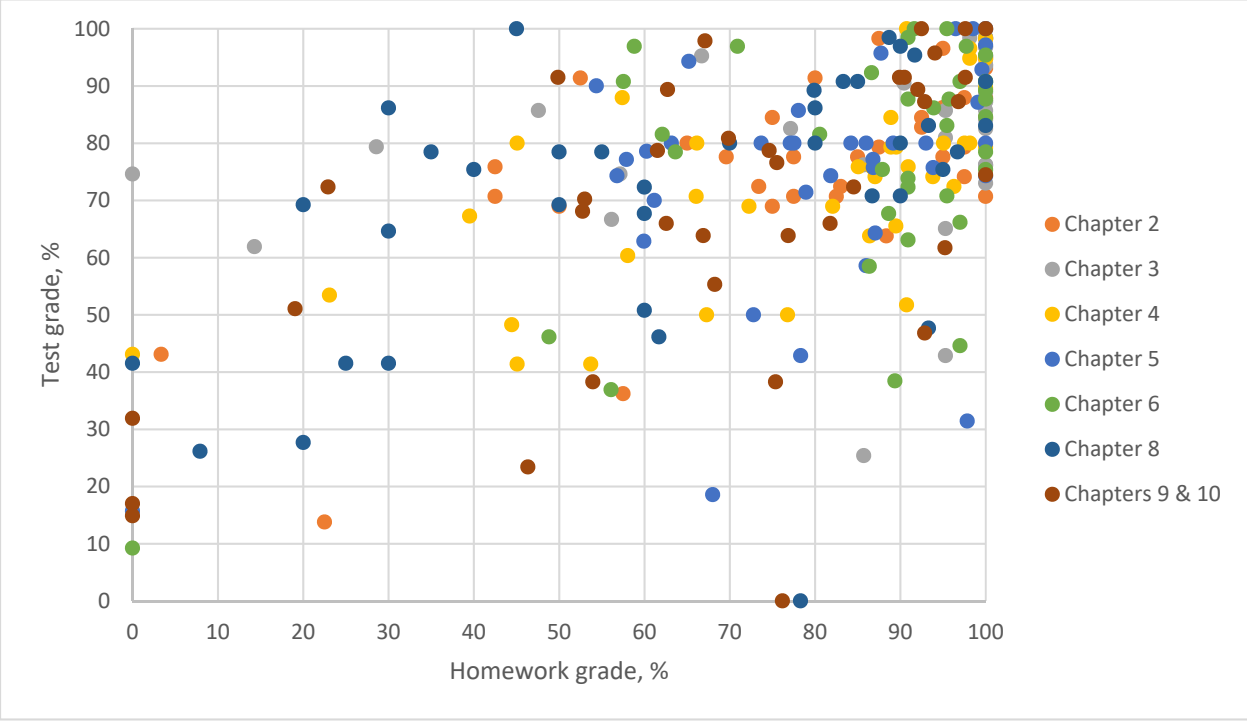

Figure 2. Spring 2023 homework and test grades

Analysis

The first question being explored was whether congruency in the questions on both the homework and the tests would result in similar performance. To address this question a correlation analysis was conducted. The results for fall 2022 and spring 2023 are shown on Table 3. The correlation coefficient represents the strength of the association between the grades on the homework and the grades on the test. Values in the range [0.60, 0.80] indicate a strong correlation, values in the range [0.40, 0.60] indicate a moderate correlation, and values in the range [0.20, 0.40] indicate a weak correlation. Overall the correlation coefficients for the spring 2023 semester are greater than those for the fall 2022 semester. Thus, there is evidence that increasing the consistency between the homework problems and test problems has strengthened the relationship between the students' performance on the homework and the tests.

Table 3. Correlation Results

Chapter	Fall 2022	Spring 2023
2	0.575	0.690
3	0.292	0.324
4	0.184	0.648
5	0.577	0.478
6	0.373	0.538
8	0.200	0.473
9-10	0.367	0.601

To further explore the relationship between the performance on the homework and the performance on the associated tests, linear regression models were developed for each chapter for each semester. The models each describe the test scores as a function of the homework scores. The results are shown on Table 4. The coefficient of determination, R^2 values represent the percentage of variation explained by the models. For each chapter except for Chapter 5, the models for the spring 2023 semester are stronger, explaining more of the variation in the data.

Table 4. Linear Regression Results

Chapter	Fall 2022	Spring 2023
2	$y = 0.469x + 44.476$ $R^2=0.330$	$y = 0.5137x + 37.012$ $R^2=0.476$
3	$y = 0.2335x + 65.729$ $R^2=0.085$	$y = 0.2047x + 66.144$ $R^2=0.105$
4	$y = 0.1779x + 70.677$ $R^2=0.034$	$y = 0.4355x + 38.839$ $R^2=0.420$
5	$y = 0.6692x + 17.447$ R2=0.332	$y = 0.4953x + 35.162$ $R^2=0.228$
6	$y = 0.2886x + 64.405$ $R^2=0.139$	$y = 0.5389x + 31.571$ $R^2=0.289$
8	$y = 0.1443x + 67.294$ $R^2=0.040$	$y = 0.3712x + 46.765$ $R^2=0.224$
9-10	$y = 0.2183x + 66.573$ $R^2=0.135$	$y = 0.5504x + 30.512$ $R^2=0.361$

The second question being explored was whether similar performance on homework and tests would translate to better test grades. Given that the difficulty of the homework increased from the fall 2022 to spring 2023 semesters, this hypothesis is equivalent to testing whether more

difficult homework leads to improved test performance. To address this question, two sample, one-tail (α=0.05) comparison of means tests were conducted for each of the seven tests, comparing the test performance between the fall 2022 and spring 2023 semesters. The results are shown on Table 5.

Table 5. Comparison of Means Test Results

Chapter	Homework	Tests
2	$\bar{x}_{2022} = 81.3, \bar{x}_{2023} = 77.1$ $P_{0.05} = 0.230$	$\bar{x}_{2022} = 82.6, \bar{x}_{2023} = 77.9$ $P_{0.05} = 0.129$
3	$\bar{x}_{2022} = 90.2, \bar{x}_{2023} = 83.9$ $P_{0.05} = 0.137$	$\bar{x}_{2022} = 86.8, \bar{x}_{2023} = 84.0$ $P_{0.05} = 0.229$
4	$\bar{x}_{2022} = 86.8, \bar{x}_{2023} = 75.0$ $P_{0.05} = 0.011$	$\bar{x}_{2022} = 86.1, \bar{x}_{2023} = 72.5$ $P_{0.05} < 0.001$
5	$\bar{x}_{2022} = 86.7, \bar{x}_{2023} = 77.3$ $P_{0.05} = 0.028$	$\bar{x}_{2022} = 75.5, \bar{x}_{2023} = 74.7$ $P_{0.05} = 0.439$
6	$\bar{x}_{2022} = 75.0, \bar{x}_{2023} = 82.8$ $P_{0.05} = 0.085$	$\bar{x}_{2022} = 86.1, \bar{x}_{2023} = 77.4$ $P_{0.05} = 0.129$
8	$\bar{x}_{2022} = 78.4, \bar{x}_{2023} = 61.9$ $P_{0.05} = 0.005$	$\bar{x}_{2022} = 78.6, \bar{x}_{2023} = 70.9$ $P_{0.05} = 0.050$
9 & 10	$\bar{x}_{2022} = 72.5, \bar{x}_{2023} = 66.7$ $P_{0.05} = 0.217$	$\bar{x}_{2022} = 82.4, \bar{x}_{2023} = 67.1$ $P_{0.05} < 0.001$

The results indicate that the homework and test scores generally decreased. The decrease in the homework scores for Chapters 4 and 8 were significant. The decrease in the tests scores for Chapters 4 and 8, and the final test covering Chapters 9 and 10 were also significant. These results do not support the hypothesis that the consistency between the homework and tests achieved through using similarly complex and difficult questions would translate to an increase in test scores.

Conclusion and Discussion

The sole conclusion, which speaks to the main focus of this study, is that when the homework questions were congruent with the test questions, there was a stronger correlation between the students' performance on the homework and the tests. It should be noted that problems given as homework were not given as test questions. That is to say that this stronger correlation does not come from students memorizing solutions. If students were to acquire a solution set or obtain solutions from social media, or purchase solutions from a company, they could potentially improve their homework scores but they would still need to study the solutions to gain the knowledge needed to complete the test problems.

It should be acknowledged that when students face difficult problems, problems for which they are not adequately prepared to solve on their own, they need help. Students in both the fall 2022 and 2023 semesters were part of a mandatory recitation program and those recitation sessions were used to help students with homework problems. The peer student teachers would go over

concepts presented in the class and work additional problems on the white board. Although not specifically evaluated, it's likely that these sessions helped to achieve the observed consistency in performance between the homework and the tests.

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