# AC 2011-2592: CORRELATION BETWEEN HOMEWORK SOLUTION WEBSITE USE AND COURSE PERFORMANCE

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# Correlation Between Homework Solution Website Use and Course Performance

## Introduction

Early in a Dynamics course at a Mid-Atlantic college in the Spring semester of 2010, students were submitting correct and thorough solutions to very challenging textbook homework problems. The solutions were unlike any that appeared in the solution manual that is published with the textbook and also unlike solutions posted by instructors at the college in previous years. Several students admitted to using an online homework solution site to complete their homework, even though there was a stated policy against copying any type of answer key to complete any textbook problem assignment. Because many students argued that the online site was helpful in learning the material covered in the assignment, data was collected for the remainder of the semester to track use of the online site and corresponding performance on course exams.

There are many online homework solutions sites; one is www.cramster.com, a site describing itself as offering "homework help for math, science, engineering, and business classes by providing resources to accelerate and strengthen the learning process"[1]. The website provides thorough, step-by-step solutions to problems in many commonly used textbooks. The odd-numbered problem solutions are free of charge; registered users must pay for even-numbered solutions. Students described the site as very useful, describing it as an online study site that helps them to work through a problem with which they are struggling. While the site has been online since February 2002, site visits during the spring semester of 2010 increased by 73% compared with the same period in 2009, with 62% of worldwide visits occuring in the United States[2].

A recent, longterm study of homework copying and its correlation with course performance was conducted[3]. In this study, the completion time between by each student of an online homework problem (posted by the instructor) was measured and used to determine whether the student was copying the solution of a peer or working through the problem themselves. Shorter time periods (less than the average time needed to read the text of the question, for example) were an indication of copying. The study concluded that homework copying has a negative correlation with performance on analytic problems in the course, but has little impact on conceptual learning. This current study was conducted to determine the correlation, if any, between online homework solution use and course exam performance. For each student, the submitted solution was compared with the corresponding solution provided by the website, and only clear copying from the website was recorded. If a student turned in no work for a given assignment, this non-submission was also recorded. Incorrect solutions were not marked as non-submissions. Even during this short, semester-long study, significant use of the website was identified. Of the 1740 collected assignments, 21% were non-submissions, and 15% of the last ten assignments were identified as having been copied from the solution website. Approximately 50% of students were identified as having used the website at least once during the test period.

The study determined that use of the online homework website had a negative correlation with exam performance. Non-submission rate, however, had a greater, negative correlation. Use of the website significantly increased when the homework problems were more difficult. In addition, students' performance on standardized tests and a prerequisite course were compared with homework solution website use, and no clear correlation appeared, indicating that students that were well-prepared for the course (where preparation was measured via standardized test and prerequisite course exam scores) were not necessarily less likely to use the homework solution site.

**Data Collection**

Cramster website use was tracked beginning during the tenth week of the 16-week semester. Throughout the semester, homework was collected at the beginning of each

class period, except on exam days. Only one problem per homework set was collected (three to four problems were assigned in each homework problem assignment), and the problem to be collected was announced immediately before collection. For each collected homework problem, the submission was compared with the corresponding solution provided by Cramster, and only clear copying of the website was recorded. For example, submissions consisting exclusively of equations that appear on the website (along with similar equation ordering and drawn diagrams unlike those appearing in the textbook or in lecture notes) were marked as copied solutions. Other submissions that looked similar to the website solution but which also contained work that did not appear online were not marked as copied solutions. Also, students were given a grade of zero only if they did not submit the collected homework problem (late submissions were accepted and given a nonzero grade). Cramster website use was tracked for the remainder of the semester for only odd-numbered problems (i.e., those that are provided free of charge on the website). All except one collected problem was odd-numbered. At the end of the semester each student's nonsubmission percentage (for the entire semester) and solution site use percentage (from when website use tracking began) was calculated.

**Results**

Sixty students from three course sections were included in the study. There were 29 total assignments collected, 10 of which were collected after Cramster website use tracking began. Of these (1740) collected assignments, 21% were nonsubmissions, and 15% of the last 10 assignments were Cramster solutions. Approximately 50% of students (29 out of 60) were identified as having used the website at least once during the test period.

*Characteristics of Cramster Users*

The current study was designed to determine the *effect* of Cramster website use on final exam performance. But a negative correlation may not necessarily indicate a

negative effect if students with high website use rates already had a disadvantage at the beginning of the semester (due to a lack of preparedness by a below-average performance for example, in a prerequisite course). In this case, a negative correlation between website use and final exam performance would not determine a negative *effect*. For this reason, Cramster website use was first compared with common measures of students' skills entering the course to determine whether a lack of preparation caused a predisposition for website use. Scores on both the SAT Math test and the final exam of the prerequisite course were normalized; the Z score for a given student's exam, $s$, is calculated by normalizing the deviation from the mean by the standard deviation, or

$$Z_s = \frac{s - \mu}{\sigma}. \tag{1}$$

Z scores for the Math SAT and the prerequisite course final exam are given by $S$ and $E$, respectively. The mean and standard deviation for each exam were calculated for students in these three sections only. A two-variable linear regression analysis gives

$$\text{Cramster use rate} = 0.16 - .001E - 0.01S. \tag{2}$$

The magnitude of the coefficients indicates no significant correlation between performance on either exam and Cramster use. Cramster use appears to be randomly distributed over all levels of student ability and preparedness, as measured by these two exams, indicating that any negative correlation between website use and course performance may indeed indicate a negative effect of website use on exam scores.

*Homework Solution Website Use and Exam Performance*

Midterm exam Z scores were calculated and plotted against website use rates in Figure 1(a). Linear regressions between these two variables for each exam gave negative coefficients ranging from $-0.30$ to $-0.39$. The mean slope of $-0.34$ is plotted in the figure. The analysis indicates that a student submitting only website-copied solutions will typically earn midterm exam scores in the course that are 0.34 standard deviations below his or her classmates that submit no Cramster solutions. It should be noted that the students with 0% website use rates do not necessarily submit all solutions;

these students may not have submitted any homework assignments at all. Eliminating students that submitted less than 60% of the homework assignments (i.e., those with greater than 40% nonsubmission rates) gives an average linear regression coefficient for this comparison of $-0.85$, indicating that, among those consistently submitting homework assignments, Cramster website use has a significant, negative correlation with midterm exam Z scores.

The significant change in these slopes motivates a two-variable linear regression relating nonsubmission rates and Cramster use rates to midterms exam performance. Because Cramster use data was only collected for the second half of the semester, the regression is used to compare the two rates to a student's average Z score on the third and fourth exams only. Results are plotted in Figure 2. The regression predicts a negative effect by both nonsubmission and Cramster use on midterm exam performance such that

$$\text{Midterm Z Score} = 0.64 - 2.09n - 1.18c, \tag{3}$$

where $n$ and $c$ are nonsubmission and Cramster use rates (i.e., percentages), respectively. The correlation coefficients with 95% confidence intervals are $-2.09 \pm 1.20$ and $-1.18 \pm 0.98$, respectively. Nonsubmission, then, has a greater, negative correlation with midterm exam performance than Cramster website use. The true correlation between website use and exam performace, however, may be strongly dependent on how the website is used by individual students. Because the amount of time spent by individual students on homework was not reported, it is possible that website users that spent significant time on the homework did benefit more than their classmates that either did not attempt the homework or spent very little time preparing a copied solution to submit.

A similar regression was also performed to compare nonsubmission and website use rates with performance on the final exam for the course. These results are plotted in Figure 3 and predict similar trends to those for midterm exam performance. The linear regression gives

$$\text{Final Exam Z Score} = 0.70 - 2.82n - 0.58c, \tag{4}$$
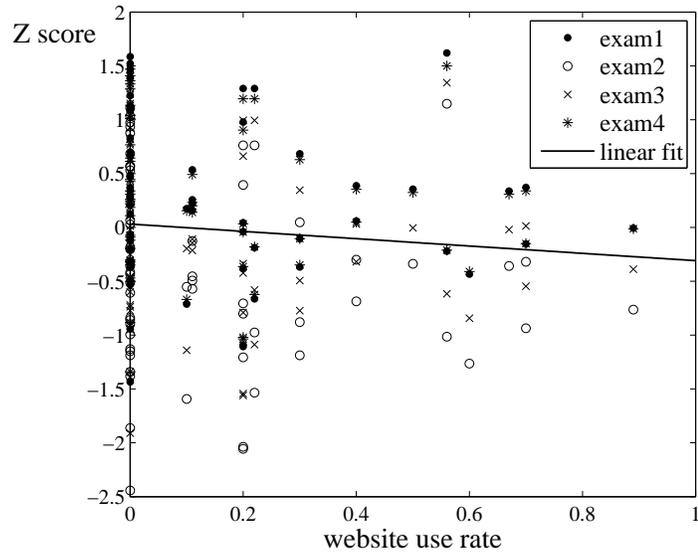
(a)
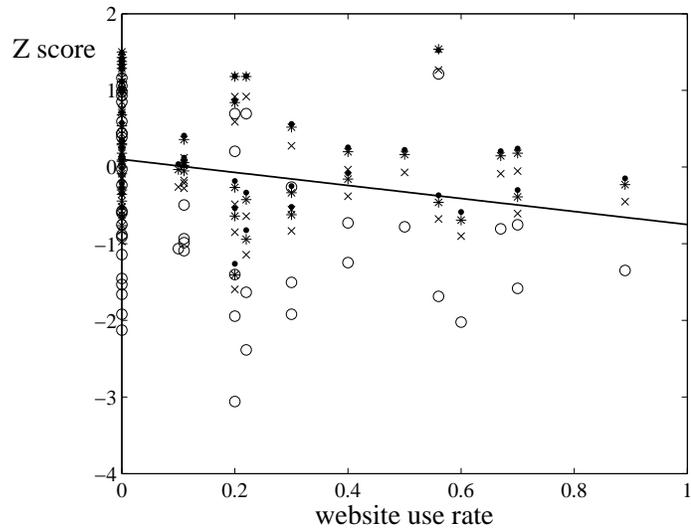


(b)

Figure 1: Midterm Z scores against Cramster use rates. (a) Linear regressions for Z scores on each exam for all students gave coefficients between $-0.3$ to $-0.39$. The best fit line for all this data has slope $-0.34$. (b) Eliminating students with nonsubmission rates greater than 40% gives linear regression coefficients between $-0.73$ and $-1.1$. The mean coefficient here is $-0.85$.
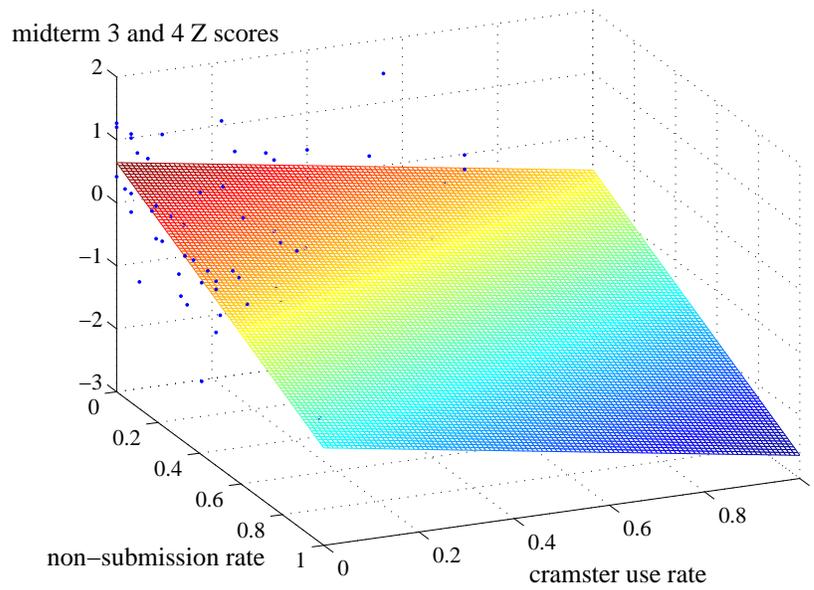
Figure 2: Mean Z scores for third and fourth midterm exams. Regardless of nonsubmission rate, Cramster use has a negative impact on midterm exam performance, but nonsubmission has a more negative impact on Z scores.

with confidence intervals for correlation coefficients of $-2.82\pm1.385$ and $-0.58\pm1.13$. Nonsubmission and Cramster use both, on average, still have a negative correlation with exam performace, but correlation is stronger for nonsubmission and weaker for Cramster website use. One possible reason for this difference lies in the content of the final exam compared with that of the midterm exams. Some problems on the final exam were very similar to those assigned for homework throughout the semester; midterm exam problems were not as similar to assigned homework problems. This difference may indicate that students benefit from Cramster website use (as compared with no significant homework completion attempt) for performance on problems that are similar to homework problems. Additionally, the final exam topics included those discussed over the entire semester, including concepts that were discussed before Cramster use was recorded. These earlier concepts were likely easier for most students, perhaps leading more students to attempt and complete the homework without website use. For this reason, website use was compared with the difficulty of assigned problems.

The students were grouped into four Cramster use categories: students using Cramster for less than 10% of all of the assignments (55% of students), between 10% and 30% (29% of students), between 30% and 50% (5% of students), and more than 50% of assignments (12%). The average rate of use for each group was then found for three phases of the collection time period. Topics covered in the course during each phase were:

1. Rigid body kinetics involving scalar kinematics equations.

2. Rigid body kinetics with rigid body kinematics involving vector kinematics equations.

3. Rigid body work and energy and rigid body impulse and momentum.

Problems in the second phase were the most difficult and involved, as they often required the generation and solution of systems of up to seven equations. The geometry of motion of bodies in this second phase was typically more complex than in
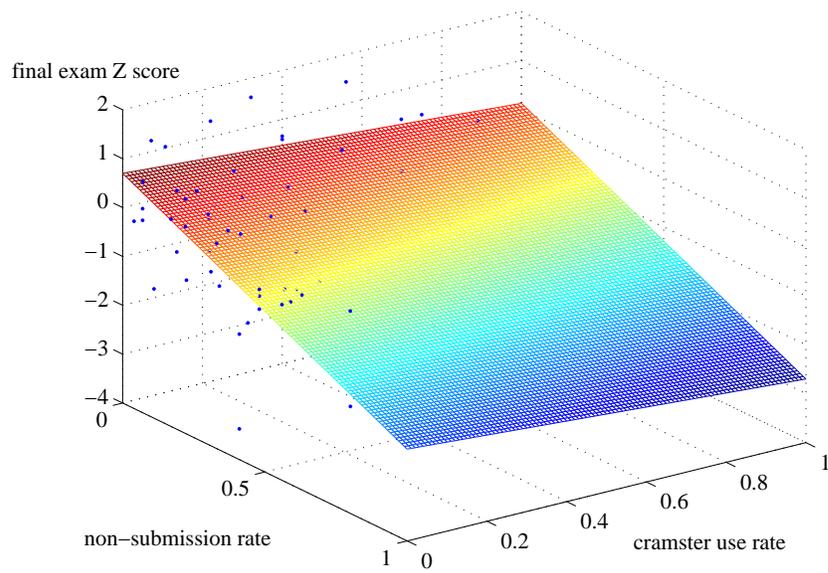
Figure 3: Linear regression of Cramster use rates and nonsubmission rates with final exam Z scores.

the first, introductory section covered during the first phase. Figure 4 plots website use by each group during these three phases, indicating that, for low, moderate, and high use groups, Cramster use was the greatest for this second, most difficult topic group. This result seems consistent with the student claim that most students may first attempt to complete an assignment without using Cramster and then use the site when they cannot begin or complete the problem.
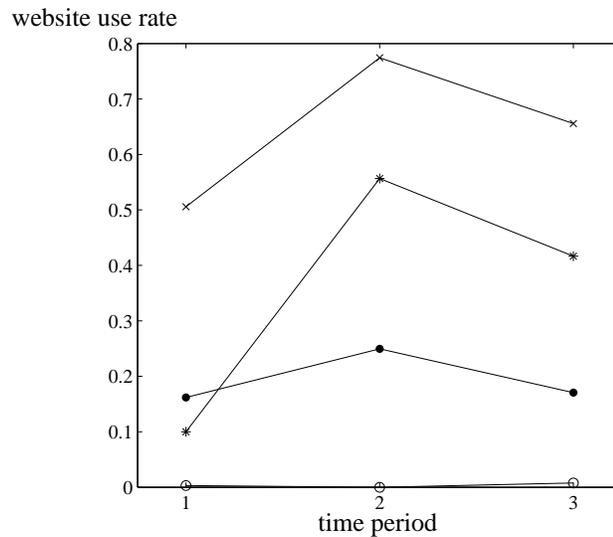


Figure 4: Cramster use, by group, over phases of the data collection time period. Groups are (from top to bottom sets) those with greater than 50% use, between 30% and 50% students use, between 10% and 30% use, and less than 10% use, respectively.

Finally, the correlation between course preparation (as measured by Math SAT scores and prerequisite course final exam scores) on final exam Z scores was compared with that of nonsubmission and Cramster use. Again, SAT scores and prerequisite course final scores were converted to Z scores, where the mean and standard deviation were calculated only for the students in these three sections. To provide a consistent scale, nonsubmission rates and website use rates were converted to equivalent Z scores ($N$ and $C$, respectively). The resulting regression is given by

$$\text{Final Exam Z Score} = 0.0 - .32N - 0.04C + 0.49E + 0.10S, \tag{5}$$

with $R^2 = 0.47$. Performance on the prerequisite course final exam has the most significant correlation with final exam performance. Here, however, all variables $N$, $C$, $E$, and $S$ can have negative values; a student submitting more than the average percentage of homeworks with little or no use of Cramster is predicted to earn an above-average final exam score.

Because the correlation between website use rates and final exam performance was not in general as strong as other correlations, there may be a significant variation in the actual use of the website. Because some students with relatively high SAT Math scores were found to have high Cramster website use rates, a regression was conducted where students were separated by these standardized test scores. When users with nonsubmission rates higher than 40% are eliminated from the analysis, the regression analysis gives

$$\text{Final Exam Z Score} = 0.03 - .18c. \tag{6}$$

But if students are separated according to their standardized test score, the regression gives significantly different results. For students with low Math SAT scores, the linear regression gives

$$\text{Final Exam Z Score} = 0.37 - 2.2c, \tag{7}$$

where a low score is defined as a score below one standard deviation of the mean. For those students scoring higher than one standard deviation above the mean, the regression gives

$$\text{Final Exam Z Score} = -0.15 + 0.95c, \tag{8}$$

giving a *positive* correlation between website use rates and final exam performance. The results suggest a significant difference in the manner in which the website is used to complete homework.

**Conclusions**

Even during a short study, significant use of Cramster was identified in this course (18% of students used Cramster for at least 30% of the homework assignments). Here,

use of the website was likely underestimated, as only clear copying of the website was recorded. This study has determined that Cramster use, in general, has a negative correlation with midterm and final exam performance in this course. There seems to be no relationship between student skills entering the course and their tendency to use the website. Cramster users cannot be easily indentified by their performance on the prerequisite course, but there is no data that tracks the use of Cramster by these students in their prerequisite course or other courses.

One very significant factor that could not be included in the study is the time spent on homework by individual students. There are likely many different ways in which students use Cramster. Some may copy a Cramster solution without first attempting the problem, others may copy the solution after beginning the problem independently, and others may only use the site after several attempts and, in those cases, may consider the step-by-step solution carefully and critically. In the sections studied, some students quietly submitted Cramster solutions without asking questions, but others seemed to use the site as they would a textbook or lecture material - as a learning tool that inspired some critical and analytical thinking. Some students asked - in- and outside of class - for an explanation of certain steps in the Cramster solution of a problem. These students seemed to be using the site as a study tool. Used as an aid after some independent work, perhaps Cramster can be another resource in conceptual learning in the course.

It should also be noted that nonsubmission had a very significant correlation with exam performance. Again, nonsubmissions were defined as students who did not turn in the assignments and not those that turned in incorrect or incomplete solutions. The importance, then, of making consistent attempts at the homework in the course was found to be very significant. This study also recorded only copying from a single website; it did not record copying from other, similar websites, and it also did not record copying between students.

Because many students argued that use of the website was actually helping them learn the material, changing the weighting of the students' homework grade on the overall course grade is unlikely to discourage students from using the website, at

least at this institution. Because this website and others provide solutions to published textbooks, creating and assigning original homework problems would certainly prevent direct copying and perhaps enourage students to use the solution websites more constructively. Additionally, students could also be given assignments about the website solutions themselves; explanations of certain steps, for example, could be requested, along with more conceptual questions related to the conditions and assumptions that must be made for any given solution step to be made.

## References

[1] http://www.cramster.com.

[2] http://www.alexa.com/siteinfo/cramster.com.

[3] D.J. Palazzo, Y. Lee, R. Warnakulasooriya, and D.E. Pritchard. Patterns, correlates, and reduction of homework copying. *Phys. Rev. ST Phys. Educ. Res.*, 6(1):010104, 2010.