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A Dozen Years of Asynchronous Learning: Using LON-CAPA for Online Problem Sets

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Abstract

An asynchronous learning system tool allows the learner to work independently without synchronizing his/her schedule with those of other people or events. This paper discusses the experience of using the LON-CAPA learning system for asynchronous problem set delivery in six engineering, engineering technology, and landscape design courses offered through the College of Agriculture and Natural Resources at the University of Delaware over a period of 12 years. LON-CAPA (web site at < http://www.lon-capa.org/>) is free, open-source, course-management software developed and supported by Michigan State University. It includes a testing and assessment component that allows for coding a variety of homework (HW) and test problems that are computer-graded and submitted by students on-line. Advantages of using LON-CAPA include:

- Students have unique numbers for their problems. Cheating is difficult. Collaborative learning is encouraged.
- The system provides immediate feedback by indicating whether submitted answers are correct or incorrect.
- Multiple attempts encourage perseverance so that students will work on the problems and remain engaged in active learning until correct solutions are obtained.
- Increased student/instructor interaction allows the instructor to “coach” students with appropriate assistance.
- All resources on the LON-CAPA system network are available for sharing with all other system users.

Courses included surveying, soil mechanics, stormwater management, and site engineering. Over 500 student-semesters of data that compared LON-CAPA problem-set performance to exam scores were scrutinized. For two courses, it was also possible to examine the relationship between exam scores and performance on conventional hand-graded problem sets. Significant positive relationships between successful completion of both types of HW problem sets and exam scores were found as were differences in results between conventional hand-graded HW and online LON-CAPA HW.

Introduction and Background

LON-CAPA[1] (Learning ONline – Computer Assisted Personalized Approach) is web-based nonproprietary course management software that has features comparable to those of well-known proprietary software packages such as Sakai[2] or Blackboard[3], but with additional capabilities in the form of sophisticated testing and assessment components to support asynchronous learning. Asynchronous learning[4] allows the student to work independently without synchronizing his/her schedule with those of other people or events. LON-CAPA integrates testing and assessment features designed to provide individualized HW assignments, quizzes, and examinations for each student. Distribution of the open-source LON-CAPA software is free through Michigan State University under a GNU license[1].

LON-CAPA is designed to run on the LINUX operating system. Coding of problems is accomplished using Perl, a powerful open-source interpreted language native to LINUX and UNIX operating systems. LON-CAPA is flexible; it can be used to create problems or questions that emphasize quantitative solutions and/or conceptual understanding. Coding of a variety of problems is possible and can include numerical, symbolic, logical, graphical, matching, multiple choice, and essay features. Problem statements can incorporate links to other resources even with animations that illustrate motion and other changes over time. Components of the problems such as values for parameters and the set of parameters itself can be randomly assigned by the computer. Students are given immediate instructor-programmed but computer-generated feedback to their responses.

Kashy et al.[5] considered the effects of using CAPA, the non-web-based predecessor of LON-CAPA, for HW problem delivery in large introductory physics classes. They investigated a number of factors including student gender, grade point average (GPA), and ACT scores. They found that the "technology can have a profound impact on learning if it is used in a way that capitalizes on its unique ability to "interact" with students, provide them with immediate feedback, and facilitate interactions among students and between students and teaching staff." They did not have a way to make direct comparisons with conventional hand-graded HW, however.

Pascarella[6] looked at learning styles of students in large introductory physics classes and how those learning styles and associated solution strategies for HW problems were related to HW problem format. Two HW problem delivery formats were examined: traditional hand-graded HW and online HW with CAPA. To encourage deeper learning for all learning styles, a relatively small limited number of attempts for the online HW was advised to prevent students from attempting to solve the problems by trial and error. Because the work was focused on exploring learning styles and problem solution strategies as they related to HW delivery mechanism, Pascarella[6] did not look at direct measures of learning for conventional hand-graded HW versus LON-CAPA.

Balascio [7] examined problems associated with conventional HW assignments. In the years before LON-CAPA was adopted, the author in his courses would typically assign four to six HW problems per week that were not graded. Students were informed, however, that some HW problems would appear on upcoming exams. To provide immediate feedback, students were given the problem answers but were required to show detailed solutions so the instructor could gage student understanding. As part of each exam, students were required to hand in several pre-worked HW problems for the topics covered on the exam that would amount to approximately 30% of the exam grade. Repeatedly, unwanted outcomes from this policy were observed that instigated a search for a more effective way to have students work actively with the course material:

- Students would put off doing the HW problems until immediately before the exams and, hence, did not get the benefit of working with the material in a timely manner right before the related ideas and principles were to be applied as a springboard to more advanced concepts.

- Students would get hung up on small misunderstandings or misperceptions while working on problems by themselves and simply give up. Many would not bother to seek help from the instructor even with constant encouragement to do so.
- Students would collaborate on solving the problems, which in itself is not bad; but typical student behavior would short-circuit the intended learning process. When collaboration degenerates into simply giving one another the solution, the person who receives the information derives no benefit; and both people are violating standards of academic honesty.
- Since students knew the answers to the assigned HW problems, they became adept at "reverse engineering" the solutions. While reverse engineering requires some ingenuity, it bypasses the learning the student is intended to derive from working the problems the "right way."
- A surprising number of students were willing to "take their chances" by doing only some of the assigned problems or just the easier ones. They were willing to gamble that either the problems they skipped would not be on the exam; or if the skipped problems did appear on the exam, they would be able to muddle their way through during exam administration.
- Because the less motivated students had not actively worked with the technical material for a sufficient amount of time, they were unprepared to work new exam problems similar to the HW.

Use of LON-CAPA was initiated for the author's courses in the Department of Bioresources Engineering at the University of Delaware in fall 2002 with support from a grant awarded by the university's Center for Teaching Effectiveness. Online problems were first developed for introductory and intermediate-level surveying courses. Surveying was chosen for the first implementation of LON-CAPA because the problems were relatively easy to code. Subsequently, problems were also developed for topics in hydraulics and hydrology for use in a stormwater management course. Hydraulics problems in particular frequently require use of subroutines and iteration to solve for quantities such as normal and critical depths in open-channels and to calculate water surface profiles.

Problems were added in 2008 for a soil mechanics course first taught in 2006. Soil mechanics problems for some of the material in that course were never converted to online delivery because of the programing complexity involved in coding the empirical graphical solutions required for some topics. Unlike in years prior to the use of LON-CAPA, these HW problems were collected for hand grading. In spring of 2014, the author taught another new course, Site Engineering, in which a mix of hand-graded HW and LON-CAPA HW was utilized. Examination of conventionally delivered HW and LON-CAPA HW problems in the soil mechanics and site engineering courses allowed for some comparisons of the characteristics of both methods.

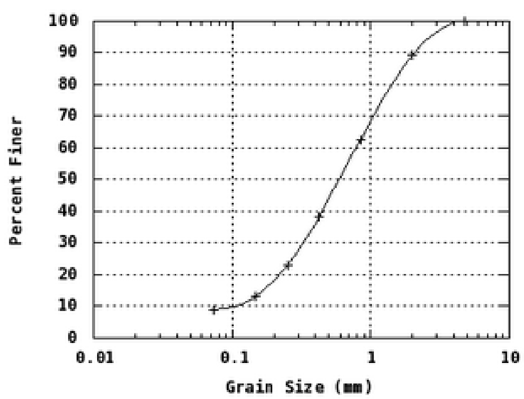
Figure 1 is the student view of a LON-CAPA problem that integrates graphical content within the problem statement. Note that every student would have somewhat different numbers and graphics. In this instance, a numerical solution is submitted, and the computer would grade the problem correct or incorrect based on the submitted answer falling within an error bound set by the problem's author. For example, the coefficient of uniformity in Figure 1, the value of which is approximately 7.29, would be graded correct for any entry between 6.93 and 7.65, an error bound of $\pm$ 5%.

To address the concerns of Pascarella[6] about students attempting trial and error solutions, students are initially allotted a maximum of five attempts to get the problems correct. If a student exhausts the quota of five tries for a particular problem, the problem can be reset. Before problems are reset, the students are required to communicate with the instructor (or a teaching assistant) about the approaches they are using to solve the problems so they can discover what they might be doing wrong. There is no penalty associated with the number of tries a student uses to solve the problems, thus giving the student an incentive to continue working on the problems until they are correct.

The following information was obtained from a sieve analysis to determine the range of particle sizes in a granular soil sample:

Sieve #	Sieve Opening (mm)	Percent Finer by Weight
4	4.76	100.0
10	2.00	89.3
20	0.84	62.4
40	0.42	38.1
60	0.25	23.0
100	0.149	13.1
200	0.074	9.0

The data plot as follows:



From the plot determine:

a) particle diameters (in mm):

D_{10}: (effective diameter)

D_{30}:

D_{60}:

Submit Answer Tries 0

b) coefficient of uniformity, C_u:

Submit Answer Tries 0

c) coefficient of curvature, C_c:

Submit Answer Tries 0

Figure 1. Student view of soil mechanics problem for particle grain size distribution illustrating integration of graphical and computer solutions.

Balascio[7] examined use of the LON-CAPA system for delivery of hydraulics and hydrology content in a problem-based learning (PBL) format – an approach that was gradually adapted for use in all the courses considered in this paper. Balascio[7] discussed the pedagogical considerations involved in the design and programming of the LON-CAPA problems and identified benefits from using LON-CAPA coupled with PBL methodology that included:

- Students have unique numbers for their problems. Cheating is difficult. Students can be encouraged to discuss with one another the concepts required to solve the problems but cannot simply give one another the answers.
- The system provides immediate feedback by indicating whether submitted answers are correct or incorrect. Immediate feedback is not possible with hand-graded assignments unless answers are posted beforehand. With posted answers, the danger is that students become adept at "reverse engineering" the solutions without really understanding how they should be obtained.
- Computer grading makes mastery based learning feasible by not requiring significant instructor grading time. Multiple attempts encourage perseverance so that students will work on the problems and remain engaged in active learning until the solutions are obtained; whereas with conventional hand-graded assignments, students may simply give up or be unaware they are doing problems incorrectly until graded problems are returned.
- Increased student/instructor interaction allows the instructor to "coach" students with appropriate assistance. Students spend less time in unproductive (and frustrating) confusion. LON-CAPA gives the instructor the ability to check values of intermediate calculations required to arrive at the solutions of each student's problems. This feature makes it possible quickly to identify the points with which the student is experiencing difficulty. Misconceptions and gaps in knowledge can be readily addressed.
- Collaborative learning is encouraged. Since all students have somewhat different problems, they can discuss amongst themselves the approaches to solving the problems but can't give each other the answers. Such mutual learning interaction between students is beneficial because students will either be required to articulate their knowledge of a subject in ways that another student can understand or will profit from getting an alternative perspective from a peer on how to approach a problem.

For the courses in question, the HW problem sets have typically counted for around 25% of the course grade. All courses include a laboratory component that counts for about 25% of the course grade, while three exams count for the remaining 50%. Since the LON-CAPA HW problems are mastery based and students can get assistance from the instructor, students can realistically expect to get full credit for all the LON-CAPA problems if they persevere and complete the problems by their deadlines. With the problems counting as a quarter of the course grade, student should have ample motivation to do so. Unfortunately, not all are so inclined. Historically, there has been much variation in student percentages of HW problem completion with some students completing all problems while others do few if any. The majority of students fall somewhere between with average completion rates in the neighborhood of 80%.

The LON-CAPA HW system has now been used in the author's courses for over twelve years. The author has written and published over 200 LON-CAPA HW problems in subjects ranging from surveying, to hydraulics and hydrology, site engineering, and soil mechanics that are available to all authors on the LON-CAPA system. While there is not an opportunity to compare student performance results in a controlled experiment between conventional methods and those obtained from LON-CAPA within a PBL framework, we can examine relationships between student performance on HW assignments and other indicators of achievement in a course. The indicator of achievement we will study will be exam scores. The conventional HW problems in use before (or in lieu of) LON-CAPA and the LON-CAPA problems have always been similar to many of the questions that might appear on the author's exams, so it would be expected that there would be a positive relationship between performance on the HW problems and exam scores.

Objective

The objective of this paper is to scrutinize the relationships that exist between student exam scores and student performance on HW problems in the courses taught by the author. Comparisons between online and conventional hand-graded HW assignments are examined.

Methods

Exam and HW data for six different courses taught since fall 2002 were compiled. The student numbers totaled 521 enrolled in 36 classes over a more than 12-year period. Table 1 provides details about the course and student characteristics.

The author's home Department of Bioresources Engineering was housed within the College of Agriculture and Natural Resources. The department never had an engineering program, but instead, beginning around 1968, offered four-year programs in Agricultural Engineering Technology, General Engineering Technology, and Bioresources Engineering Technology that by the late 1980s were ETAC of ABET accredited. By the early 2000s, a single ETAC of ABET accredited four-year program in General Engineering Technology (ET) was available.

For a variety of reasons, the Department of Bioresources Engineering and the ET program were phased out by spring of 2013. The author now has a home department of Plant and Soil Sciences with a joint appointment in the Department of Civil and Environmental Engineering, which accounts for the loss or revision of some courses and the pick-up of a new course, PLSC 331. As indicated in Table 1, the author's classes have often served a variety of majors within each class. Various mixtures of agriculture, engineering technology, and engineering students have been typical. For the data analysis performed in this study, no attempt has been made to organize HW and exam data into separate blocks; all student data were aggregated together.

For the first offering of EGTE 104 in fall of 2002, only the mid-term exam was included in the data set because a security breach was experienced that put the LON-CAPA system out of service just after the mid-term exam was administered. Improved security measures have prevented additional problems. Development of new problem resources puts considerable demands on instructor time. During the initial implementation period for the surveying courses and BREG 321, the author's time was allocated for LON-CAPA resource development. Once the project was underway, all conventional homework problems in those courses were converted to online delivery through LON-CAPA.

Table 1. Information about courses in the study.

Course	Title and Notes	Semesters	# of Students
EGTE 104	Introduction to Surveying, 1 credit lab course for engineering technology (ET) and agriculture majors	5	69
BREG/CIEG 113	Introduction to Surveying, 3-credit lecture/lab course for civil & environment engineering (CIEG), ET, and agriculture majors	8	171
BREG/CIEG 223	Intermediate Surveying, 3-credit lecture/lab course for CIEG and ET majors	6	54
BREG 312	Fundamentals of Soil Mechanics, 3-credit lecture/lab course for ET majors. Includes conventional hand graded HW assignments and on-line LON-CAPA problems.	6	58
BREG 321	Stormwater Management, 4-credit lecture lab course for CIEG and ET majors	10	161
PLSC 331	Landscape Construction Systems, 4-credit lecture/lab course for ornamental horticulture & design majors. Includes conventional hand graded HW assignments and on-line LON-CAPA problems.	1	8

BREG 312, Soil Mechanics, was first taught in fall 2006. All soil mechanics problems for that year and 2007 were conventional hand-graded HW. By the time the course was taught a third time in spring of 2008, LON-CAPA problems had been developed for material covered in the first two exams. Material for the last third of the course did not lend itself to easy development of LON-CAPA problems, so HW problems for that portion of the course remained conventional hand-graded assignments throughout the remaining three times it was taught.

For BREG 321, the LON-CAPA problem sets were only employed for material on the first two exams, so those were the only exam scores used. During the last third of the class, students were assigned to several teams for group work on a multi-part stormwater management design project. The final exam for the course focused on the design process.

PLSC 331 was taught just once in spring 2014. A mixture of conventional hand-graded HW and web-based LON-CAPA HW was assigned throughout the course, so it was not possible to isolate exam scores associated exclusively with either method of HW delivery. The LON-CAPA problems constituted 188 out of a total of 433 HW points or about 43% of the HW problems assigned in the course. The small sample size (8 students) rendered the results less reliable.

Table 2. Aggregate HW% and exam data for seven courses.

Course	# of Obs.	HW %	exam averages %
EGTE 104 Introduction to Surveying (104)	70	84.70	76.02
BREG 113 Introduction to Surveying (113)	171	82.51	69.17

BREG 223 Intermediate Surveying (223)	54	80.93	65.64
BREG 312 Fundamentals of Soil Mechanics (312)	41	83.17	71.59
BREG 312* Fundamentals of Soil Mechanics	58	70.96	67.22
BREG 321 Stormwater Management (321)	161	84.10	75.95
PLSC 331** Landscape Construction Systems (331)	8	79.66	71.82

* Data for conventional hand-graded HW and associated exams.
** Mix of LON-CAPA and conventional HW for all exams. LON-CAPA HW average % was 73.20; conventional HW average % was 83.06.

Table 2 summarizes the HW and exam data for these courses. As noted earlier, a broad mix of student majors were typically present in some of these classes. No attempt was made to separate out any effects of student major.

Results and Discussion

Inspection of the data in Table 2 suggest that there may be differences among the courses with respect to HW and exam statistics. To help define the statistical model or models to be used for data analysis, the first question investigated was whether a single statistical model might be sufficient to describe the data. Since PLSC 331 involved a mix of LON-CAPA and conventional HW for all exams that could not be segregated, the data for that course were omitted from this analysis. It was not assumed that the same model parameter values could describe the relationship for conventional HW as for LON-CAPA HW. A simple linear regression model was examined for the remaining five courses:

$$Y_{ij} = a_i + b_i X_{ij} + \varepsilon_{ij}$$

Where,

i = course index, $i = 1,\ldots,5$
j = student index for course, $j = 1,\ldots,n_i$
n_i = number of students in i^{th} course.
Y_{ij} = exam score for j^{th} student in course i.
X_{ij} = HW percent for j^{th} student in course i.
a_i = intercept for course i
b_i = slope for course i
ε_{ij} = error term ~ normally distributed with mean zero and variance σ_i^2 for course i.

To test whether one regression line can be used for all courses, the following null hypothesis is posed[8](pg 212):

- H: $\eta_{ij} = a + bX_{ij}$
- A: $\eta_{ij} = a_i + b_i X_{ij}$ $\quad i = 1,\ldots,5;\ j = 1,\ldots,n_i$

The first condition that must be met for a single regression line to be appropriate is homoscedasticity or equivalence of variance among the seven courses. Bartlett's test for homogeneity of variance was used[8](pg 212). Table 3 provides data for the six courses needed to perform Bartlett's test for the null hypothesis:

H: $\sigma_1^2 = \sigma_2^2 = \cdots = \sigma_5^2$.

With a pooled estimate of variance equal to 141.65, a χ^2 value of 63.89 is calculated which is considerably greater than the critical value, 9.49, for α = 0.05 and (5-1) = 4 degrees of freedom. Therefore, the null hypothesis is rejected; there is at least one course variance that differs. In fact, for pairwise comparisons amongst the five courses using either Bartlett's test or the F-test[8](pg 126), only two pairs of courses were found to have equivalent variances for α = 0.05: 1) EGTE 104 ⇔ BREG 223 and 2) EGTE 104 ⇔ BREG 312. With the bulk of courses having unequal variances, the data were not pooled and subsequent analyses were done on a course-by-course basis.

Simple linear regression was used to examine the relationships between LON-CAPA HW performance and exam scores for the five courses shown in Table 3 plus PLSC 331. Table 4 summarizes the regression results.

Table 3. Course data for Bartlett's test of homoscedasticity

Course	i	n_i	SS deviations from independent variable mean $\sum_{j=1}^{n_i}(X_{ij}-\bar{X}_{i.})^2$	SS deviations from dependent variable mean $\sum_{j=1}^{n_i}(Y_{ij}-\bar{Y}_{i.})^2$	Sum of Cross-Product Terms $\sum_{j=1}^{n_i}(X_{ij}-\bar{X}_{i.})(Y_{ij}-\bar{Y}_{i.})$	Sample Variance by course s_i^2
104	1	70	21578.28	11647.08	6907.65	138.76
113	2	171	30520.32	48100.95	17228.68	227.07
223	3	54	14551.48	5415.09	1625.26	100.65
312	4	41	13860.64	6874.95	4098.90	145.20
321	5	161	15521.14	13398.06	6963.81	64.61

Table 4. Results of regression analysis for LON-CAPA HW performance vs. exam scores.

Course	# of obs.	Intercept	Intercept std error	Intercept = 0 Probability	Slope	Slope std error	Slope = 0 Probability	R-Square
104	69	48.90	6.94	0.0000	0.320	0.080	0.0002	0.190
113	171	22.59	7.21	0.0020	0.564	0.086	0.0000	0.202
223	54	56.61	6.87	0.0000	0.112	0.083	0.1851	0.034
312	41	46.99	8.72	0.0000	0.296	0.102	0.0063	0.176
321	161	42.40	4.75	0.0000	0.399	0.056	0.0000	0.245
331	8	52.32	10.45	0.0024	0.266	0.137	0.0990	0.388

For BREG 312 and PLSC 331, it was possible to examine the relationships between conventional hand-graded HW assignments and exam scores. Conventional HW percentages could be aligned with specific exam grades for BREG 312, but LON-CAPA and conventional HW assignments were mixed for all exams in PLSC 331. Thus, the data in Table 4 for PLSC 331 are just for exam scores vs. LON-CAPA HW percentages even though conventional HW assignments would have been used to cover some of the material on each exam.

Table 5 shows regression data for exam scores versus conventional HW assignments for BREG 312 and PLSC 331. Again, material on the exams would have been covered by both LON-CAPA and conventional HW assignments; but the data in Table 5 are for exam scores vs. conventional HW scores, only. The data for 331* aggregates the LON-CAPA HW problem percentages with conventional HW percentages into a single HW score that is approximately 43% LON-CAPA and 57% conventional hand-graded.

Table 5. Regression analysis for exam scores vs. conventional HW percentages

Course	# of obs.	Intercept	Intercept std error	Intercept = 0 Probability	Slope	Slope std error	Slope = 0 Probability	R-Square
312	58	39.34	6.65	0.0000	0.393	0.090	0.0000	0.252
331	8	8.71	0.34	0.7685	0.760	0.339	0.0660	0.456
331*	8	33.54	16.57	0.0894	0.481	0.205	0.0575	0.478
*HW data for conventional and LON-CAPA assignments were combined. HW portions were about 43% LON-CAPA and 57% conventional.								

In general, the data for all courses were highly variable. Figure 2 shows the data and regression line for exam scores vs. LON-CAPA HW percentages for BREG 321. This figure is typical for the courses examined. Figures 3 and 4 show data for BREG 312 for which it was possible to analyze exam and homework data for both conventionally graded HW assignments and LON-CAPA online assignments. The data points in Figures 2, 3, and 4 are widely scattered and R^2 values for all courses listed in Tables 4 and 5 are low as would be expected for data as scattered as those in Figures 2, 3, and 4.

Inspection of Table 4 indicates that the linear relationships between exam scores and LON-CAPA HW were significant at the 5% level for all courses except BREG 223 and PLSC 331. The intercepts for both BREG 223 and PLSC 331 were significant, however. For conventional hand-graded HW, Table 5 indicates that a significant linear relationship exists only for BREG 312. Given the small sample size for PLSC 331, the analysis may be unreliable, however. Additional years of data may help clarify.

If the individual HW assignment data for BREG 312 in years 2006 and 2007 still existed, it would be possible to separate out the HW assignments that were for material on the first two exams and obtain a linear regression model of exam scores vs. conventional HW percentage for just those data. That regression model could then be compared to the one obtained for the four subsequent years for exam scores vs. LON-CAPA HW percentages. That would allow direct comparison of the two approaches for exactly the same course material. Unfortunately, the only data available for 2006 and 2007 had been aggregated for the whole year. We can, however look at the results for the 17 observations that occurred during 2006 and 2007 and compare them to those obtained for the 41 observations from the four years the instructor taught the course between 2008 through 2013. If for years 2008 through 2013 we look at performance on all exams vs. overall HW percentage, the LON-CAPA HW represents the majority of the HW points, about 60%. Table 6 provides a summary of those results.

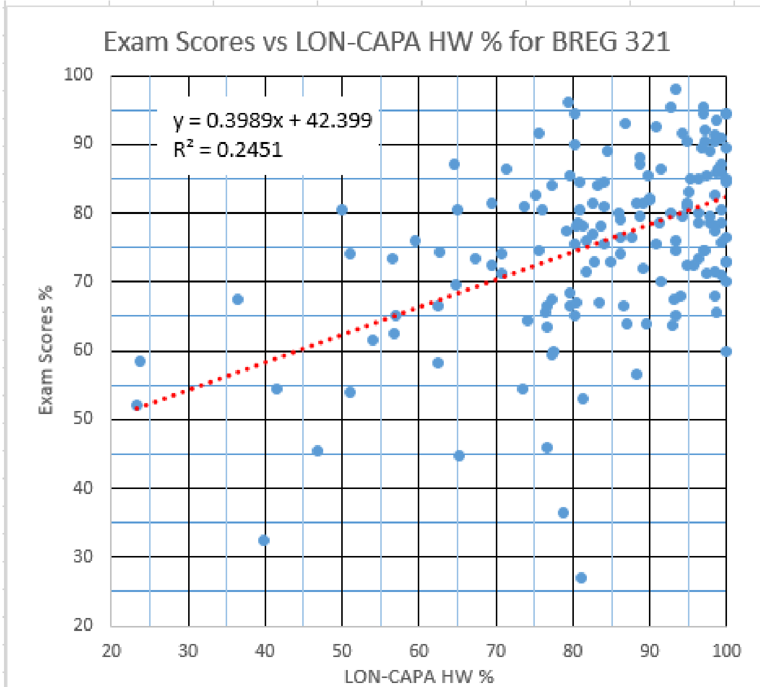


Figure 2. Linear regression line for BREG 321 exam scores vs. LON-CAPA HW %, n = 161

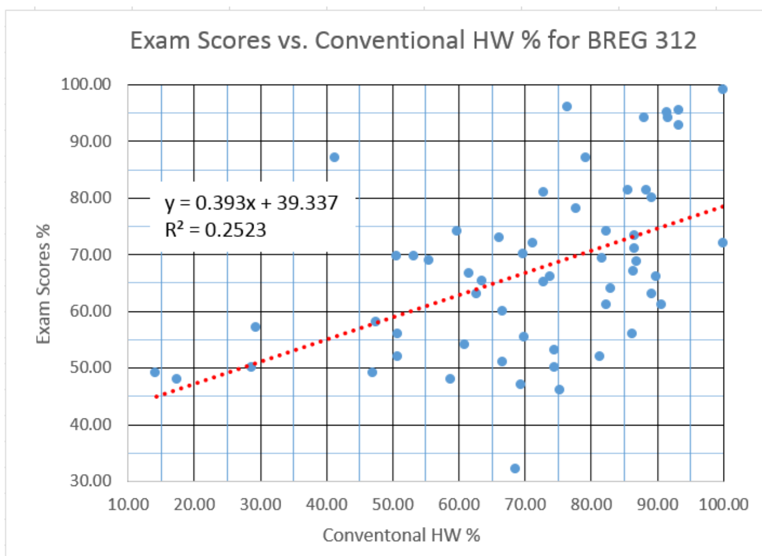


Figure 3. Linear regression line for BREG 312 exam scores vs. conventional HW %, n = 58.

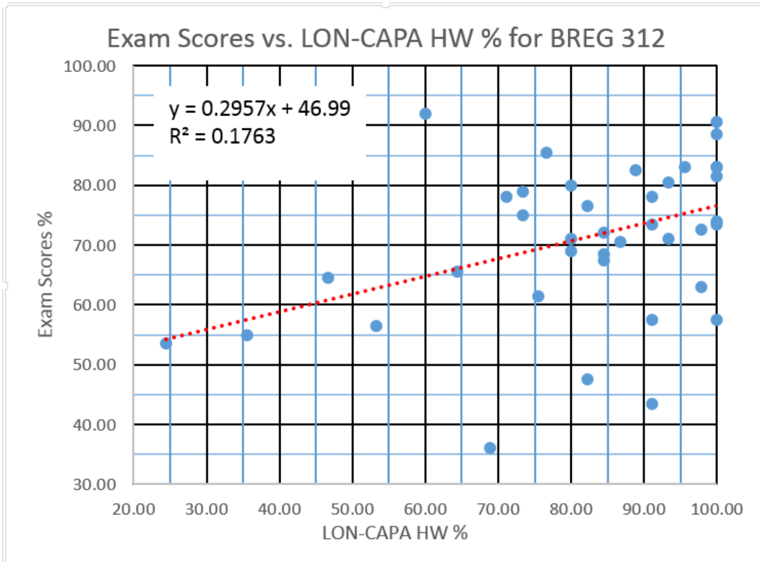


Figure 4. Exam scores vs. LON-CAPA HW % for BREG 312, n = 41.

Bartlett's test[8](pg. 212) was used to determine that the BREG 312 variances for the 100% conventional HW data set and the 60% LON-CAPA, 40% conventional HW data set used to obtain the results in Table 6 were statistically equivalent at the $\alpha = 0.05$ level ($p = 0.39$). More detailed examination using the methods in Ostle and Mensing[8](pg. 210) revealed that the regression models shown in Table 6 were statistically different for $\alpha = 0.05$ ($p = 0.001$). Further investigation (after Ostle and Mensing, pg. 213) [8] showed that the slopes were different at the $\alpha = 0.05$ level ($p = 0.006$).

Table 6. BREG 312 Regression analysis for exam scores vs. HW% for two mixes of conventional (Conv.) hand-graded HW and LON-CAPA (L-C) HW.

composition HW %		# of		Intercept	Intercept = 0		Slope	Slope = 0	
Conv.	L-C	obs.	Intercept	Std. Error	Probability	Slope	Std. Error	Probability	R-Square
100	0	17	39.07	12.25	0.0061	0.477	0.155	0.0077	0.387
40	60	41	43.80	7.45	0.0000	0.325	0.094	0.0013	0.235

A single-sided t-test[8] (pg. 118) was used to test the null hypothesis:

- H: The regression constant in the BREG 312 regression model for exam scores vs. the mix of conventional and LON-CAPA HW% is less than or equal to the regression constant for the model of exam scores vs. conventional HW%.
- A: The regression constant in the BREG 312 regression model for exam scores vs. the mix of conventional and LON-CAPA HW% is greater than the regression constant for the model of exam scores vs. conventional HW%.

With 54 degrees of freedom, the null hypothesis was rejected for $\alpha = 0.05$ ($p = 0.0378$). Thus, the regression constant, 43.80, for exam scores vs. a mix of conventional HW% and LON-CAPA HW% is greater than the regression constant, 39.07, for exam scores vs. conventional HW%. The conversion of 60% of homework assignments to web-based LON-CAPA HW assignments has a significant effect on the relationship between HW performance and exam scores.

Though the data for PLSC 331 shown in Tables 4 and 5 do not show the linear regression models are significant for $\alpha = 0.05$, they would be significant at $\alpha = 0.10$, which is not a terribly weaker level. In addition, the results for PLSC 331 shown in Tables 4 and 5 are consistent with the results obtained for BREG 312. Table 4 shows results of regressing exam scores vs. LON-CAPA HW% with no conventional data included. Since a mix of about 57% conventional and 43% LON-CAPA assignments were used throughout the semester, the LON-CAPA assignments covered less than half of the material.

Data for PLSC 331 in Table 5 include only conventional HW assignments, while those for PLSC 331* in Table 5 combine the two types of HW into a single overall percentage. The combined HW data yield the best regression model, most likely because the combined HW scores are more indicative of a student's overall preparation for the exams since all subjects on the exams are covered.

Interestingly, when multiple linear regression was used to analyze PLSC 331 exam scores regressed against the two independent variables, conventional HW% and LON-CAPA HW%, all parameters in the model were highly insignificant. Table 7 lists those results.

Table 7. Multiple linear regression for exam scores vs. LON-CAPA and conventional HW % for PLSC 331.

Independent Variables		Coefficients	Std. Error	P-value
	Intercept	14.55	47.81	0.7731
LON-CAPA	X Variable 1	0.0486	0.3032	0.8790
Conventional HW	X Variable 2	0.6466	0.7977	0.4544

How might these data be reasonably interpreted? Balascio et al.[9] looked at self-reported out-of-class time devoted to various course activities and how it related to a student's final course grade for several ET courses. Out-of-class activities were broadly categorized as: 1. Completion of Graded Assignments, 2. Review of Class Notes and Reading Assignments, and 3. Study Time for Tests and Quizzes. Completion of graded assignments was the activity on which the majority of out-of-class time was most typically spent – up to 75% in some cases[9]. The data were gathered for six different courses over 17 course-semesters for a total of 186 students. A second-order function of out-of-class time was found to be a statistically significant predictor of ultimate course grade ($p < 0.01$), but the predictive value was weak with an R^2 value less than 0.07[9]. They also considered the relationship between a student's GPA and final course grade. GPA turned out to be a far stronger predictor of final course grade ($p < 0.0001$, $R^2 = 0.348$) than out-of-class time spent on course-related activities – to the extent that any parameter based on time spent on the course was insignificant whenever GPA was included as an independent variable[9].

While we must be aware that correlation is not causation, there are obviously strong significant relationships for all courses except BREG 223 and PLSC 331 between the exam and HW data examined here. The weaker results for PLSC 331 may have been influenced by a small sample size consisting of only eight students. BREG 223 was laboratory oriented with two laboratories and only one lecture per week that may have discounted the importance of HW problems. For courses other than BREG 223 and PLSC 331, the exam scores vs. HW% relationships are stronger than the relationship between out-of-class time and final course grade found by Balascio et al.[9]. The predictive worth as indicated by the R^2 values is more comparable to that Balascio et al.[9] found for course grade vs. GPA.

Two notable observations from the BREG 312 data in particular are that the slope of the exam scores vs. LON-CAPA HW% regression line is shallower than the slope for exam scores vs. conventional HW%, while the intercept for the LON-CAPA HW line is greater than that of the conventional HW line. The data for PLSC 331, the only other course for which both conventional HW and LON-CAPA HW data were available, are consistent with these observations, even though the results are not significant at $\alpha = 0.05$.

An F-test confirmed that the variance of the LON-CAPA and conventional HW% values for BREG 312 are equivalent at $\alpha = 0.05$. The average values of HW% for LON-CAPA (83.17%) and conventional HW% (70.96%) displayed in Table 2 were found to be statistically different, however. Specifically, a one-sided t-test confirmed that LON-CAPA HW% average was higher than the conventional HW% average for $\alpha = 0.05$ ($p = 0.0011$).

Recall that the LON-CAPA problems are delivered in a mastery-based format. With multiple attempts allowed and instructor-assistance encouraged, sufficiently motivated students can realistically expect to get full credit for all problems. These results indicate that students may be taking advantage of the mastery-based nature of the LON-CAPA problems to complete correctly a higher percentage of the LON-CAPA problems than for the conventionally graded HW. The grand average for all LON-CAPA HW% over all courses except PLSC 331 was about 83.22 – not significantly different from the value for BREG 312 by itself.

The situation for PLSC 331 was markedly different. Students in this class scored more highly on the conventional HW problems than on the LON-CAPA problems by 83.06% to73.20%, respectively. Other than the small sample size, the difference might be explained by the characteristics of the students in this class. All students in PLSC 331 were Landscape Horticulture and Design majors, most of whom were not strong mathematically. Since most of the LON-CAPA problems were computationally oriented, these students may have been more comfortable and persistent with hand-graded assignments that tended to be more visual and qualitative. Students in the other classes were predominately engineering technology or engineering students, the large majority of whom were numerate.

The explanation for the difference between the LON-CAPA and conventional HW regression models can, perhaps, be mostly explained by the mastery-based format. Many students who did not get all the LON-CAPA problems correct would still have spent a considerable amount of time-on-task working with the material – probably because of the immediate feedback and the multiple attempts allowed. Many persisted in working on the problems and interacting with the instructor until the problems were solved. In contrast, students did not know if they had done conventional hand-graded HW correctly until it had been graded and returned. Even then, many students may not have bothered to examine the corrected HW to determine what they did wrong.

The additional time-on-task engaged in problem solving that was encouraged by the mastery-based approach on average had benefits that were manifest in somewhat higher exam scores regardless of how many HW problems were ultimately left incorrect. This mechanism is revealed statistically by the larger positive constant in the linear regression equations for LON-CAPA vs. conventional hand-graded HW data from BREG 312. With average scores on the LON-CAPA HW problems higher than those for conventionally graded HW problems, a larger regression constant, and an upper limit on the exam scores response variable of 100%, the smaller slope of the regression line for the exam score vs. LON-CAPA data becomes inevitable. This same mechanism would no doubt occur in any course where a mastery-based approach was used.

Summary and Conclusions

Heteroscedasticity of model variances was found among the courses, so the data could not be aggregated across courses but needed to be examined on a course-by-course basis. Significant positive linear relationships between exam scores and HW% were obtained for four of the six courses examined. For one of the other two courses, PLSC 331, the relationships would be significant for $\alpha = 0.10$. Through comparison of the results for BREG 312, for which both conventional hand-graded HW and LON-CAPA HW data were available, it was determined that the effects of the two HW formats are different. Specifically, the mastery-based nature of the LON-CAPA HW problems imparts a boost to average exam scores, perhaps by encouraging students to be more persistent in working the problems and thus to be more engaged with the material. This effect is manifest in a larger regression constant for the exam score vs. LON-CAPA HW% data for BREG 312.

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