Is Computer-Graded Homework an Effective Tool in Introductory Statistics?

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Abstract
After thirty years of instruction and ten years of considering program assessment in statistics and course-wide assessment in introductory statistics, it seemed time to concentrate on an individual course in a systematic way rather than in an ad hoc manner. Now that large sections and prepackaged, automated online homework are the reality, we wondered how students compare on the course-wide final with students in previous years, using the same instructors and the same text but no automated online homework. In this article, we present a comparison of assessment results from students in elementary statistics courses using automated online homework with assessment results from students in courses not using automated online homework.

Key Words: Assessment, Introductory Statistics, Learning, Teaching, Online Homework,

1. Introduction
There are both advantages and disadvantages to the use of automatically graded online homework as opposed to paper and pencil hard-copy homework. Some of the advantages to the students include:

- Random problem generation enables students who study together to discuss the methods and concepts appropriate to the problem without straight copying of homework.
- Immediate feedback on the correctness of the response
- Multiple attempts on the same concept with different data and/or different context.
- Indication of which section of the text is appropriate to study
- Automatic grading

Advantages to instructors include:

- Immediate recording of homework grades
- Tracking of student performance
- Identification of common problem areas so that the instructor can review the misunderstood concepts
- Less time-consuming than grading hard-copy homework, allowing the instructor more time to develop course materials and modify teaching to fit the students' needs.

Disadvantages to online homework in comparison to hard-copy homework include:

- Online homework is primarily multiple choice
- Detailed feedback on problem-solving work including arithmetic and algebra is not possible
- Students get a question "wrong" when simple arithmetic errors are made but the general approach to the problem is correct
- The students have less practice in written expression of statistical concepts

However, with the advent of large classes and limited budgets for teaching assistants and/or graders the use of online homework provides the instructors with more time to develop the course itself, the ability to easily track students' performance and have electronic homework grades readily available. From the students' perspective online homework provides immediate feedback and useful electronic tools (online text, video lectures) for studying.

Tracking results on a common test is a good method of overall assessment of student learning and teaching methods. Norton and others (1999) summarize a faculty wide report investigating our introductory statistics course and an assessment of students' common statistical knowledge. Similarities between non-statistics students' results were compared with results of statistics majors/minors. Summaries of the Department results of assessments in our introductory courses appear in several *Proceedings of the American Statistical Association Section on Statistical Education* (Norton and others between 2000 and 2008; see references). The student learning outcomes in this course are consistent with the fundamental learning goals discussed in Garfield and Ben-Zvi (2007).

With the recent availability of online resources, faculty and publishers have begun to develop sophisticated tools to further enhance the learning environment. One of these tools is automatically-graded online homework. Generally, online homework is integrated with other learning supports such as auxiliary videos on specific topics and links to sections in electronic textbooks.

Recent research on the effectiveness of online homework is mixed. Chua-Chow, Chauncey and McKessock (2011) found many benefits to the use of online homework in a large introductory business statistics course (~700 students); in that study the online-homework students performed significantly better on a common final exam than the hard-copy-homework students (average increase from 62% to 67%). However, in their study the hard-copy homework students did not receive grade credit for the homework, so they may be showing the value of feedback on homework rather than the improvement due to online versus hard-copy homework. These authors also provide a literature review on the use of online homework in other academic areas. Ward (2004) found no significant difference in student performance, as measured by grade in elementary statistics course, when comparing a hybrid course (some on-campus, some online) with an on-campus course. However, Ward did find that the hybrid students had a more positive attitude towards the course (measured by a ten question survey, each response on a Likert scale). Utts and others (2003) also found no significant difference in course performance between a hybrid and on-campus introductory statistics course, but found that the hybrid students were slightly less positive about the course than the on-campus students.

Students seem to accept online homework positively. Doorn, Janssen and O'Brien (2010) conducted a survey of nearly 700 students in a variety of economics courses and an introductory business statistics course using different online systems for homework. Twenty-seven percent of those surveyed were in the introductory statistics course and 83% were either in the introductory economics courses or the introductory statistics courses. On a five-point Likert scale (Strongly Agree, Agree, No Opinion, Disagree, Strongly Disagree) the survey showed that the majority of students either "Strongly Agree" or "Agree" that online homework worked well (91.7%), helped with understanding of the material (77.7%), helped with preparation for tests (71.2%), like the flexibility in pace (92.7%) and would recommend the use of online homework systems (70.8%). Slightly under 50% found the feedback helpful (45.4%).

In this study we compared performance in our introductory statistics course between six sections of the course using online homework and nine sections of the course using hard-copy homework only.

2. Methods

At California State University East Bay students are required to complete a quantitative methods course. The course often selected for this requirement is our introductory, non-calculus based, elementary statistics course. We offer up to ten sections of the course per quarter and the classes are often filled to capacity of around 50 students. The large class size provides a challenge for the instructors to give the students adequate feedback on homework. Consequently, in 2011-2012 we adopted an online homework package that accompanied the course. The online package included homework problems, online textbook and auxiliary videos on specific topics.

Our department implements a twenty-question multiple choice assessment test given at the end of the quarter. This instrument tests competence in literacy, skill, and thinking. In this study, the results of this instrument are used to compare the effectiveness of using on-line homework versus using only hard-copy turned in homework. A fixed effects general linear model is used with the effects of instructor (three levels) and on-line homework (two levels) to assess significant differences in mean results on the assessment test.

Three instructors contributed data from both hard-copy homework only sections (nine sections) and on-line homework sections (six sections). The overall teaching methods differed by instructor, including some courses that were given in a computer lab with the students having full access to software when completing assignments and tests. The same textbook was used for all sections (although the online section has a customized version of the text and an electronic version). Students in the online-sections were given the option of purchasing a hard-copy text (custom version) or using only the electronic textbook ($10 more to purchase the hard-copy). Students in the hard-copy sections had to purchase the hard-copy text and reference copies were available in the library.

Overall performance on the assessment test is compared using a generalized linear model with fixed effects for homework-style and instructor. A *t*-test is also performed comparing the mean results between “online” and “hard-copy” students.

3. Course and Data

3.1 Course Description

The course used for comparison is an introductory statistics course use for the general education quantitative reasoning requirement at California State University East Bay. The prerequisite is mastery of an elementary level mathematics (ELM) requirement which demonstrates a reasonable level of proficiency in high school mathematics.

This lecture course typically has 45 – 50 students per section with no additional laboratory or study sections. Typically, the instructor has a graduate student grader for hard-copy hand-in homework. Some instructors give the course in a computer lab with student use of Excel and Minitab.

The catalog course description is cited here.

*STAT 1000:*Elements of Probability and Statistics (5)
Descriptive statistics (measures of central tendency, dispersion, correlation), elementary discrete probability distributions. Introduction to tests of statistical hypotheses. *Prerequisite: completion of ELM requirement. Not open to students with credit for STAT 2010 or 2008. Must complete course with a grade of "C-" or better in order to earn General Education, Area B4, credit.*

3.2 Student Body

This course is taken to fulfill the general education quantitative reasoning requirement (a very small minority of the students take this as their first course in a statistics major program). Many of the students have not passed the initial ELM test and must have successfully completed from one to three quarters of remedial mathematics courses before taking STAT 1000.

The bar chart (Figure 1) below shows the class level and the number of remedial courses taken for students in two recent sections of the course (n =98). These sections used online homework. One of the sections had 2 graduate students which is very unusual. Sixty-seven percent of the students had taken at least one remedial math course. Figure 2 shows the course-grade distribution by number of remedial courses (p-value < 0.001 with three F's deleted from the analysis of variance).

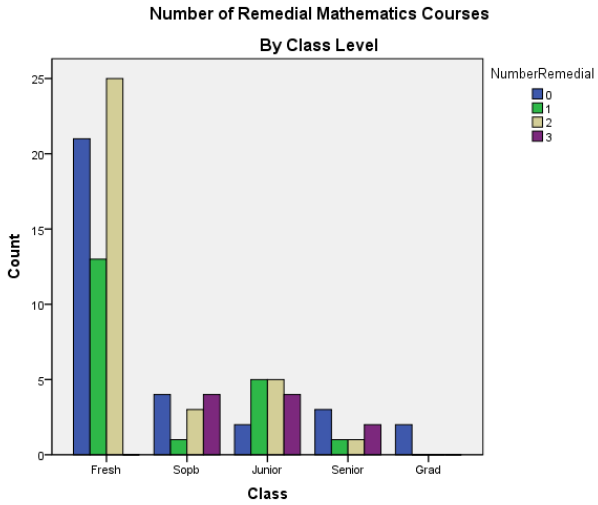

Figure 1: Number of Remedial Math Courses by Class Level

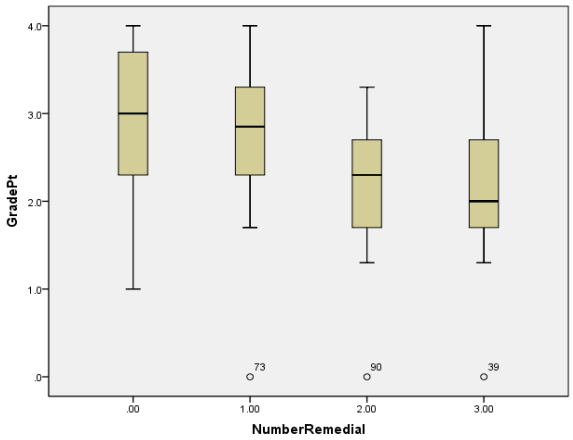

Figure 2: Course Grade by Number of Remedial Math Courses (0 - F to 4 –A)

3.3 Textbook and Online Homework

All the instructors used the same textbook for the course. For the years of comparison the text used was *Mind on Statistics* by Utts & Heckard. The online homework program used was provided by *Aplia* and coordinated with Cengage Learning. A customized-text, *Statistics 1000 with Aplia*, containing only the chapters covered in the 10-week course was developed by the publisher (the complete text was available to the students electronically).

The online homework provided several formats for homework:

- Publisher provided problems in which the students had up to three attempts to complete the problem
  - Concept of each of three attempts is the same but the context changes
  - Hints and references to relevant section of the text provided
- Instructor can write problems (no multiple attempts option)
- Instructor can upload problems from the textbook (no multiple attempts option)

All of the above options provide immediate feedback to the student on the correctness of the response. And the system provides immediate electronic grade for both the student and the faculty. The faculty member can also track the percent complete on each homework before it is submitted. Additional resources provided by the online part of the course:

- Video tutorials on selected topics
- Interactive normal distribution and binomial distribution table-tools (these enable the student to interactively change the parameters and move vertical boundaries on graphs of the resulting distribution to find probabilities)

3.4 Data

Table 1 shows the number of sections taught by each of the three instructors by quarter and year. Online homework was used during the academic year Fall 2011-Fall 2012. The lack of balance with respect to "without online homework" and "with online homework" within instructor is apparent.

Table 1: Sections of Stat1000 by Quarter/Year and Instructor (n = 567)

Quarter_Year	Instructor 1	Instructor 2	Instructor 3
Fall 2007		2 sections (40,44)	
Spring 2008	2 sections (38,47)		
Fall 2008	2 sections (35,42)		
Winter 2009	2 sections (44,37)		1 section (28)
Fall 2011_Online	1 section (41)	1 section (31)	2 sections (42,40)
Winter 2012_Online			2 sections (34,24)

Results

A boxplot of the assessment test score (0 – 20 points) is shown in Figure 3. The variability of scores within each section is considerable (section means differ from 9.6/20 to 14.6/20 with most means around 11; standard deviations vary from 2.7 to 3.7). Table 2 shows the summary statistics.

In a model with fixed-effects of "instructor" and "online," each of the main effects (p-value < 0.0001) and the interaction (p-value = 0.0005) is significant. Within instructor 1 there is no significant difference between the course sections; within instructor 2 the single online-section has a significantly lower mean (by roughly 2 points) than either of the other two sections; within instructor 3 the single non-online-section mean is significantly higher (by roughly 3 points) than each of the online-sections. However, the high imbalance within instructor makes these results suspect. Overall the mean of all the non-online scores and the mean of all the online scores do not differ significantly.

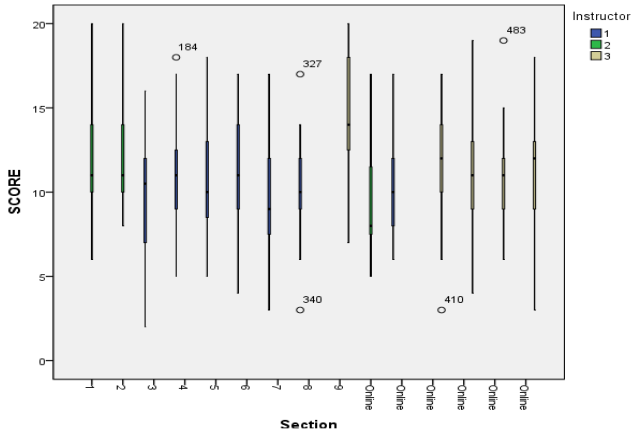

Figure 3: Scores on a Common Twenty Question Assessment Test by Quarter and Section.

Table 2: Summary Statistics for Common Assessment Test with 20 Points Total Quarter/Year and Instructor (n = 567)

Quarter_Year	Instructor 1	Instructor 2	Instructor 3
Fall 2007		$\bar{x}$ = 11.8 s = 3.8, n = 40 $\bar{x}$ = 12.0 s = 2.9, n = 44	
Spring 2008	$\bar{x}$ = 9.9 s = 3.3, n = 38 $\bar{x}$ = 10.9 s = 2.9, n = 47		
Fall 2008	$\bar{x}$ = 10.9 s = 3.7, n = 34 $\bar{x}$ = 11.8 s = 3.8, n = 42		
Winter 2009	$\bar{x}$ = 9.6 s = 3.1, n = 44 $\bar{x}$ = 10.2 s = 2.7, n = 37		$\bar{x}$ = 14.6 s = 3.6, n = 28
Fall 2011_Online	$\bar{x}$ = 10.5 s = 3.7, n = 41	$\bar{x}$ = 9.6 s = 3.2, n = 31	$\bar{x}$ = 11.6 s = 3.2, n = 42
Winter 2012_Online			$\bar{x}$ = 11.3 s = 3.2, n = 40 $\bar{x}$ = 10.9 s = 2.8, n = 34 $\bar{x}$ = 11.2 s = 3.4, n = 24

Discussion

Data from our Stat1000 assessment examination has been collected for a number of years. Online homework has only been used for the last academic year. Consequently, there is an abundant amount of data for the course without-online-homework and relatively little data for the course with-online-homework. Thus, the results shown in this study can be considered a pilot study. In general, our study indicates that students perform comparably on a common assessment test using online-homework versus hard-copy homework in an introductory statistics course.

There are many caveats to analyzing whether online versus hard-copy homework is more effective for our elementary statistics course. Primarily, the data are from an observational study. In 2011 we adopted online homework and the sections without online homework are from previous years. Consequently, time may be a factor in the analysis as both student body and faculty teaching practices may change over time. The class size changes from $n = 28$ to $n = 47$ and this also may have an influence on student performance. From a modeling viewpoint the data are unbalanced with respect to all of the factors. The imbalance of the "online" sections versus "hard-copy" sections made it not possible to compare "online" versus "hard-copy" within instructor.

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