Positive Statistical Impact of Online Homework Assignments on Exam and Overall Course Grades

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Abstract

This work evaluates the impact of introducing homework assignments, which are 1) assigned and submitted online, 2) algorithmic, and 3) not from the course textbook, on students' homework performance relative to their exam and overall class performance. The aforementioned technique of online homework assignment is compared to the traditional technique where homework problems are assigned from the course textbook with students submitting the solutions on paper. These two (paper and online) homework techniques are applied to the undergraduate junior course on 'Heat Transfer', a required course for students majoring in mechanical engineering, over two separate semesters (Spring 2016 and 2018). The findings show that, compared to traditional paper homework technique, the aforementioned online homework technique improved the correlation between homework scores and exam scores by over 99%, and between homework scores and overall end-of-semester scores by over 43%. The latter may be slightly skewed due to a 5 percentage-point increase of online homework contribution in overall score, but nevertheless shows a significant improvement. Quizzes are also analyzed for the two semesters. Thus, online homework assignments, if done correctly, can be a powerful tool to enhance the educational impact in an engineering class.

Introduction

During a semester, students typically spend their maximum time outside of the class on homework assignments (compared to other class activities/assignments). The primary purpose of homework assignments in an undergraduate engineering course is to 1) solve problems, and 2) help students gauge their understanding of topics based on their homework scores. Thus, homework performance should be directly tied to a student's exam and overall class performance, and homework scores should be a good indicator of his/her continuous standing in the class; for example, if he/she is falling behind and needs to catch up, homework score should act as an early warning sign before an exam.

Traditionally, in an engineering course, homework problems are assigned from the course textbook with students submitting the solutions on paper. A comprehensive study by Fernandez et al. [1] looked at homework as an outcome assessment for four courses (statics, fluid mechanics, water resources engineering, and engineering administration), and found such graded homework to be a statistically insignificant predictor in determining students' performance on tests or final exam. Strongest correlations were found between quizzes and tests/final exam. The study highlighted the need for developing more effective and efficient homework assignment approaches.

One approach which has gained popularity over the past decade is online homework. Increasing class sizes have made such an approach attractive as it has the potential to free up many hours for

faculty [2] to enhance the student experience in the course as well as concentrate on research. Some studies have been performed to date on online homework assignment. Most of these studies have found online homework to be an effective approach. Head and Owolabi [3] found that use of online homework in an engineering mechanics course improved student grades thus suggesting an enhancement of student learning. Jones [4] used the Canvas based online homework in an engineering materials course which resulted in higher scores on exams and a higher correlation between homework scores and exam scores; this finding was attributed to the immediate feedback on the correctness of the problem as well as allowing multiple attempts to solve the problem. Liberatore [5] used an online homework system that asks the same questions of each student while changing one or more numeric values in the problem statement, and observed statistically significant improvements in student achievement in material and energy balance topics. Taraban et al. [6] used online homework in a thermodynamics class and found improved students' grades on in-class tests; online homework resulted in effective learning as students received immediate feedback and did not have to wait as in the case with paper submissions. However, two studies (Davis and McDonald [7] in mechanics course, and Bonham et al. [8] in a physics course) assessed the effect of online vs. handwritten homework on the success of the students, and found no significant difference between either techniques.

This research utilizes online homework in a 'Heat Transfer' course, but takes it a step further by assigning algorithmic problems not available in the course textbook for nearly all homework assignments. The impact of this technique on exam and overall course grades is statistically compared to the traditional paper submission technique (where homework problems are assigned from the course textbook with students submitting the solutions on paper) over two separate semesters and cohorts (Spring 2016 and 2018).

Methodology

'Heat Transfer' is an undergraduate junior-level 4-credit required course for students majoring in mechanical engineering. Homework, quiz, exam and overall final grades are analyzed for two different cohorts over Spring 2016 and Spring 2018 semesters. The same textbook was used in both semesters: 5th edition of "Heat and Mass Transfer: Fundamentals and Applications" from publisher McGraw-Hill Education [9], and the course was taught by the same instructor. The weighted grading scale for each semester is shown in Table 1.

Table 1: *Weighted grading scale for 'Heat Transfer' course in Spring 2016 and 2018 semesters*

	Spring 2016	**Spring 2018**
Enrollment	76	79
Homework	10 % (paper submission)	15 % (online submission)
Quizzes (in-class)	20 %	10 %
Design Project	10 %	10 %
3 Exams (including final, in-class)	55 %	55 %
LearnSmart Practice (online through software)	n/a	10 %
Attendance	5 %	---

The Spring 2016 course had homework problems assigned from the course textbook and students submitted each homework assignment on paper, i.e. students would solve the problems on paper and submit to the instructor/TA for manual grading.

The Spring 2018 course had online homework assignments. Students used *Connect* [10] software by publisher McGraw-Hill Education for the same textbook to access and submit the homework assignments (e-book is provided along with the software). Two important aspects of the online homework were: 1) each question was algorithmic (i.e. students would get the same set of questions but one or more numeric values in each question was randomly changed by the software, and 2) questions were not from the course textbook. This combination of creating one's own question and making it algorithmic is a feature in the software. An example of such a question is shown in Figure 1.

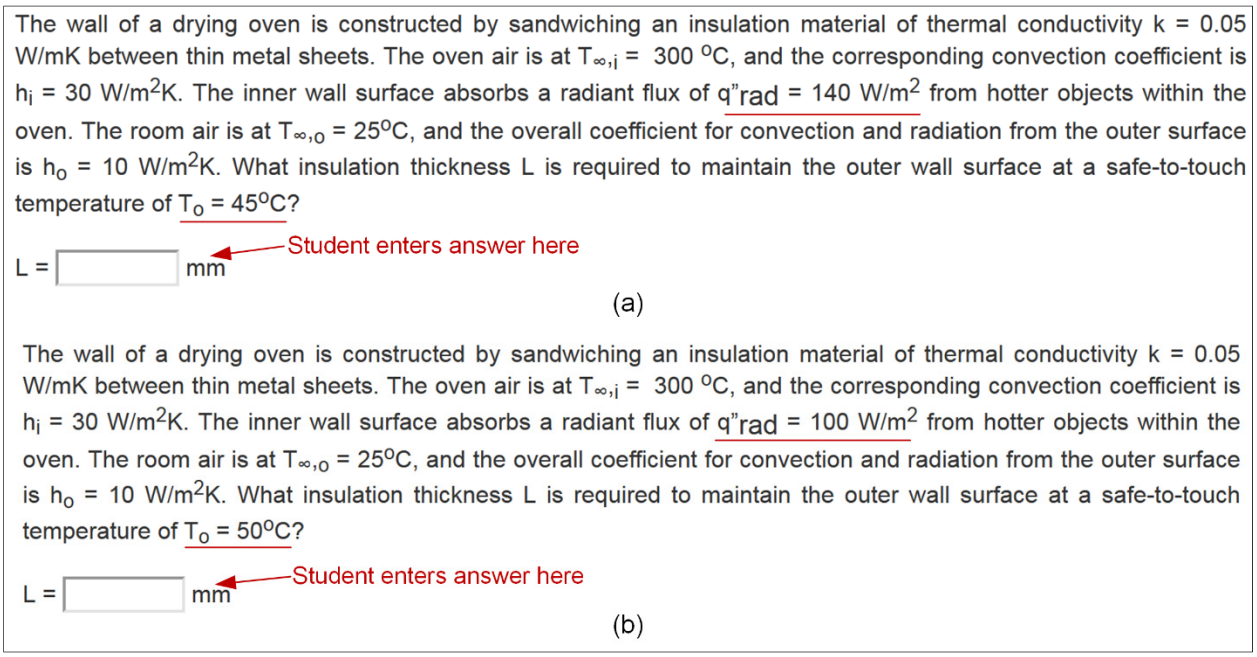

Figure 1: *Sample of algorithmic homework question assigned to the students taken from a different source [11] other than the course textbook and manually entered into the software; similarly, own questions can also be created. Randomized numerical values for the same question are underlined in (a) and (b); each student gets the same question with varying numerical values.*

The students work on solving each online homework question, but only enter the final answer, as shown in Fig. 1. The solution steps are not submitted to the instructor and each assigned question is graded automatically by the software, thus resulting in either full score (if correct) or no points (if incorrect) for that question. Such an exercise may raise concern on grading, correcting and providing feedback on the problem solving steps to the student (as is done with paper submissions). This flaw is partially mitigated by allowing multiple submission attempts as explained next.

Three submissions are allowed for each assignment without any penalty. After each submission attempt, a student immediately sees correct or incorrect indicator for each entered solution along

with question score and total assignment score. At this point and depending on number of submission attempts left, the student can try correcting the incorrect solution on his/her own or can decide to discuss with the instructor or TA. This immediate feedback on the incorrectness of the entered solution allow the students to identify and/or seek help on the error and rework the solution unlike paper submissions where they receive the graded homework after waiting a few days and then have to re-familiarize with the questions and solutions. Further, a tolerance limit can be set for the expected solution of each question. Order of questions is scrambled for each student, and the software is setup to take the highest score of the three submission attempts.

Results and Discussion

Scores of all homework, quizzes, exams, etc. (as per Table 1) were collected for the two semesters. All the scores were scaled out of 100 to study the impact of paper vs. online homework submission on the exam and overall course scores. Figures 2a and 2b show the curves for homework and overall scores for each student in Spring 2016 and Spring 2018, respectively, where the scores are arranged in increasing order of the overall course score. For example, in Fig. 2a (Spring 2016 data), student #59 who earned an overall score of ~85/100 received ~77/100 in homework score. Thus, the disparity between the paper homework submission and the overall course score can be visually seen for Spring 2016 semester (Fig. 2a), but the relation improves for online homework submission in Spring 2018 semester (Fig. 2b).

Table 2 compares the average scores of homework, quizzes, exams and overall course for the two semesters. A key observation is that the homework average dropped by over 8 points from paper to online submission even though three submission attempts were allowed in the latter. This finding shows that 1) students had to spend more effort in solving the online homework algorithmic problems from an unknown source, and/or 2) possible copying/plagiarism (which occurs in paper submission) may have been significantly reduced. The latter possibly tends to occur more in students performing poorly who do not spend the required effort to solve homework problems. Thus, online homework appears to be a better predictor of overall course grade especially for students who performed poorly in the course.

Table 2: *Average scores of students out of 100 in the Spring 2016 and 2018 courses.*

	Spring 2016	**Spring 2018**
Homework average	83.88	75.84
Quiz average	78.27	68.76
Exam average	68.71	68.74
Overall course average	75.18	73.23

In addition to score averages and visual observation, Matlab was used to statistically analyze the similarity between data sets. Pearson correlation coefficients were calculated between different data sets, and are shown in Table 3. A rule of thumb for correlation coefficient values less than 0.30 indicate little if any relationship between the data sets, while values in the range of [0.40, 0.60] indicate a moderate degree of correlation, and values ≥ 0.6 indicate a strong degree of correlation [1].

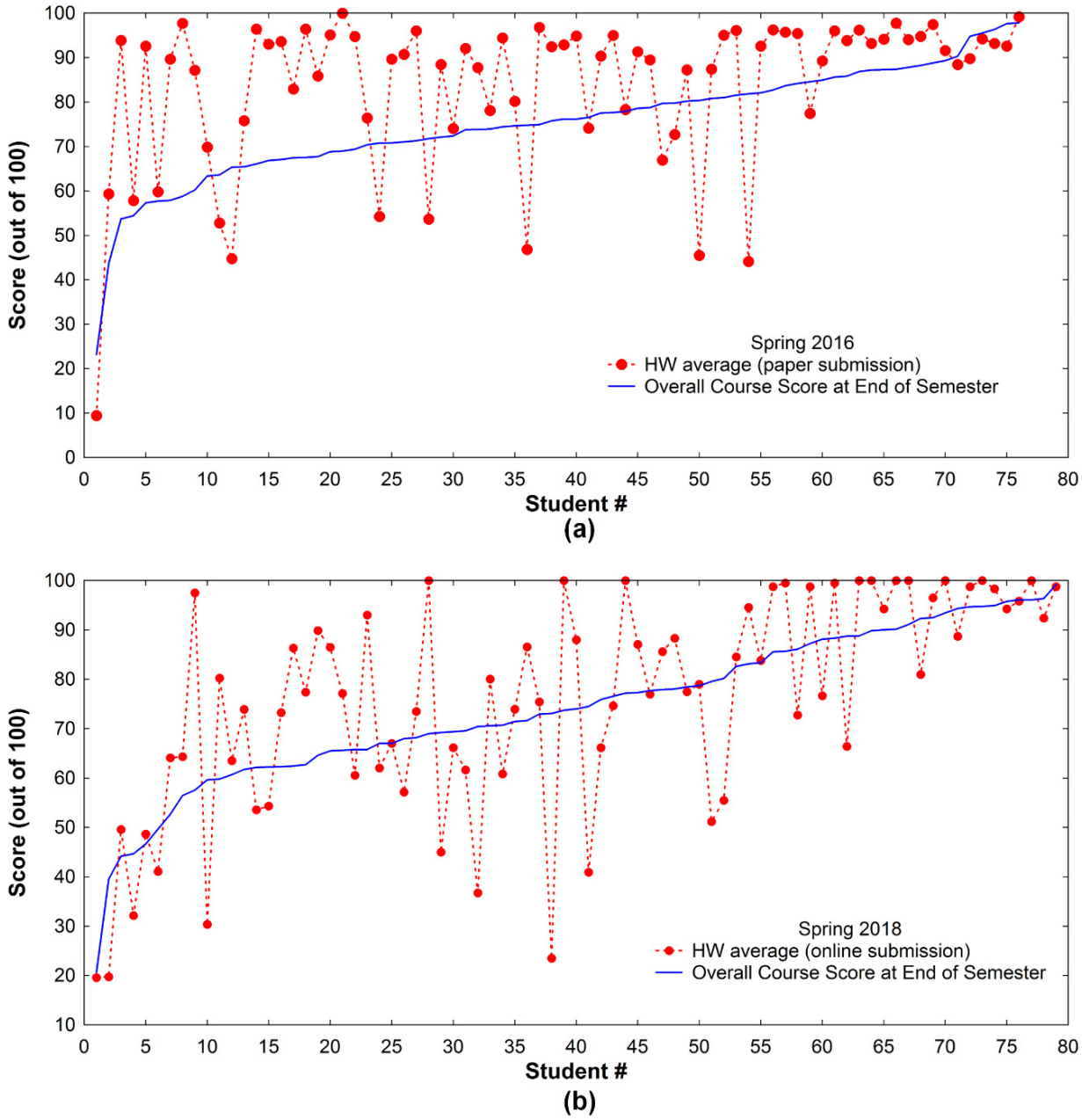

Figure 2: *Comparison between average homework scores and overall course score in 'Heat Transfer' for (a) Spring 2016 and (b) 2018 semesters. In the paper submission, the homework problems were assigned from the course textbook. In the online submission, the homework problems were algorithmic and assigned from a different source rather than the course textbook.*

As seen in Table 3, paper HW submission provides no significant correlation with the exam score, while the online homework submission presents a moderate correlation with exam score, an improvement of over 99%. This suggests that the traditional technique of paper submission of homework problems assigned from the textbook is an extremely ineffective way of instruction for heat transfer and typical numerical-problem-heavy engineering courses. Online homework, similar to the effort undertaken in this paper, which enforce students to solve their own assignments while reducing the chances for copying/plagiarism presents an effective way of

assessing student learning. The correlation between homework and overall course score was higher as the overall course score includes weighted homework score (note: online HW submission in Spring 2018 accounted for a 5 percentage-point weight increase in overall score compared to paper HW submission in Spring 2016, as shown in Table 1). Online homework shows over 43% improvement from paper homework submission for predicting the overall course outcome for a student. The other correlations estimated in Table 3 show quizzes are a better indicator for predicting exams and overall course score, as expected. Also, exam scores show a very strong correlation with overall course score because they constitute a majority of the overall score.

Table 3: *Pearson correlation coefficients for comparison between different data sets*

	Spring 2016 (paper HW submission)	**Spring 2018** (online HW submission)
Homework and Exams	**0.2447**	**0.4871**
Homework and Overall Course Score	**0.4870**	**0.7005**
Homework and Quizzes	0.5143	0.5691
Quizzes and Exams	0.6472	0.7570
Quizzes and Overall Course Score	0.8315	0.8397
Exams and Overall Course Score	0.9428	0.9494

Conclusion

The study presented here utilizes a unique way of online homework submission, using *Connect* software from McGraw-Hill Education, where algorithmic questions can be created from any different source other than the course textbook. This technique ensures that students have to work on their individual assignment as numerical values are randomly changed, while also reducing chances of copying/plagiarism as the questions created can be from a variety of sources and/or one's own questions. Homework, quizzes, exams and overall course score data are collected for two semesters, one with traditional paper homework submission while the other with online homework submission as stated above. The scores are analyzed using Pearson correlation coefficient which is a method to capture the level of similarity between two data sets.

Statistical analysis shows that this unique online homework submission is a significantly better predictor for exam score prediction, showing an improvement of over 99% compared to traditional paper homework submission. The paper homework submission showed no statistically significant relation with exam scores. Online homework submission also showed a 43% improvement in predicting overall course score compared to paper homework submission; this result may be slightly skewed due to a 5 percentage-point weight increase of online homework contribution in overall course score, but still shows a significant improvement. Thus, this unique online homework methodology can potentially help in early identification of students who are falling behind in the course, and can serve as a powerful and continuous student learning assessment outcome tool.

Acknowledgement

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