Evaluation of Canvas-Based Online Homework for Engineering

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Introduction

Computer based (online) homework is an alternative to paper-and-pencil (paper) homework. The homework assignments are hosted online and students submit their answers online as well. The student's answers can be evaluated automatically by comparing the student's answer to an instructor provided correct answer or the student's work can be manually evaluated by the instructor. Online homework with automatic grading has been utilized to some extent in science and math courses to accommodate larger class sizes without significantly increasing the instructor's time commitment associated with grading homework.[1,2] As class sizes increase the time commitment for grading has also increased which may lead to reduced homework assignments or grading of only specific problems thus providing feedback to the students on only a few problems. Adopting online homework in engineering, especially for larger classes, may allow for more practice with problems outside of class (time-on-task) for the students while actually alleviating some of the obligation of grading for the instructor.

There are a few rigorous studies of online homework in the literature and most articles focus on how the homework is implemented rather than evaluate the effect of online homework.[3,4] Dufresne, et al., have compared online homework to paper homework in physics and found that online homework resulted in better exam performance.[5] Porter and Riley compared the use of computer-based homework assignments with paper homework assignments from the textbook in an introductory statistics course and found that students who used the computer-based homework performed better. Reports of students preferring online homework and performing better on exams in physics,[2,6] chemistry,[7,8] and calculus [9,10] are available. While it seems online homework is superior, counter examples can also be found. For example, Bonham, et al., compared online homework to paper homework in an introductory physics course and found no statistical difference in student performance.[11] Hauk and Segalla found no difference between online homework and paper homework in an algebra course.[1] Cheng, et. al, evaluated graded and non-graded paper and online homework along with various teaching methods in an introductory physics course and found that whether the homework was graded or not made a larger difference in student performance.[12] Palocsay and Stevens found no difference in using online homework for a business statistics course,[13] and Pascarella found that online homework hindered metacognitive behavior in physics. [14]

Many publishers of engineering textbooks provide online practice and homework for students, for example, the MasteringEngineering system from Pearson, or the Connect system from McGraw-Hill. Typically, the publisher based online homework is tied to a specific book and requires students to pay more to use the system. There are currently only a few titles in engineering disciplines that have online homework/practice available through the publisher. The instructor is required to choose the textbook for the course based on the available titles. While these systems have additional capabilities, such as providing links to locations in the text associated with the problem the student is working on, it does have the limitation of only

providing homework on topics in the textbook. If the instructor chooses to add additional information to the course, those topics will not be included in the publisher based homework assignments.

An alternative to publisher based online homework is to use a learning management system's built-in capability. Many learning management systems such as Blackboard or Canvas have the capability to administer quizzes to the students. This quiz capability can be used to create online homework assignments that cover topics not included in the textbook and can be either automatically or manually graded. The following includes a qualitative and quantitative analysis of the impact of online homework administered through the Canvas learning management system in a junior level Engineering Materials course.

The online homework was implemented and evaluated in an Engineering Materials Course. The Engineering Materials course is a junior level course that is offered both Spring and Fall semesters. The enrollment is usually between 75 and 110 students, depending on the semester. The student population is predominantly junior level students pursuing a B.S. in Mechanical Engineering with a few students from other disciplines such as Biomedical Engineering and Motorsports Engineering. The course was taught by the same instructor over the length of the study. The course is lecture based with homework assignments, quizzes, and three exams. The remainder of this paper has the quantitative results, qualitative results, and implementation details of using Canvas for online homework.

Quantitative Results

Online homework was evaluated by comparing the performance of students in the class from two different semesters. One semester utilized paper-based homework assignments while the other semester utilized all online homework assignments. All other aspects of the course remained the same, i.e. the same lectures, the same number of quizzes and the same number of exams. The course includes three exams, two in-class exams and one final. The course final was the same for both semesters but the in-class exams, which are returned to the students, were different. All exams for the course were written by the same instructor and every attempt was made to make them of similar difficulty. Both semesters had the same homework problems which included both conceptual and computational problems. The paper-based homework class had 100 students and the online based homework class had 78 students.

Overall there are 112 different problems over the different assignments for the online homework. For the class of 78 students using online homework, this results in 8736 possible problem submissions. Out of those 8736 problems, 163 (1.9%) were not submitted. Five students accounted for the majority -119, approximately 73% of the 163 missing assignments. In comparison, the traditional paper-based assignment had the same problems but distributed differently (with part a, part b etc.) resulting in 7700 possible problem submissions. Out of these 7700 problems, 433 (5.6%) were not submitted. In this case, six students accounted for a significant portion of the missing submissions. To further evaluate the data the missing submissions were divided into five categories. The first category was assignments missing one problem in the assignment, in other words, the student skipped one problem when trying to solve

the homework assignment. The remaining categories were assignments where the students skipped approximately one-quarter of the problems, one-half of the problems, three-quarters of the problems, or failed to submit the assignment at all. While this data does not indicate if the student's answer is correct or not, or the level of effort in solving a problem, it does indicate if the student even attempted to solve the problem. Table 1 summarizes the homework submission data divided into the five categories.

As can be seen in Table 1 there is an obvious difference in online and paper homework. While it seems the tendency to skip some of the problems in a single assignment is approximately the same, the tendency to completely ignore a homework assignment is much greater in the case of traditional paper-based homework (39 skipped assignments) than in online homework assignments (3 skipped assignments).

Table 1. Number of students missing problems on assignments, a blank indicates no problems were missing for any of the students. The Sum row indicates the sum of the column.

	1-problem missing		**¼ of problems missing**		**½ of problems missing**		**¾ of problems missing**		**Nothing Submitted**	
	Paper	Online	Paper	Online	Paper	Online	Paper	Online	Paper	Online
HW 1	3									
HW 2		1	1				1		1	
HW 3	3	1	4			2	1	1	1	2
HW 4				3		1			4	1
HW 5		1	3	2	2			2	2	
HW 6	1			2	2	3			6	
HW 7	1	1	1	5	3	1			8	
HW 8	2	1	3	5					6	
HW 9		3			3				8	
HW 10	1	3	8	4	1				3	
Sum	11	11	20	21	11	7	2	3	39	3

The Canvas Learning Management system tracks additional information about the students' experience with the homework. For example, it tracks the number of attempts at solving a problem if multiple attempts are allowed. It will also report the time it took to complete the problem. Unfortunately, the time to complete the problem is not representative of the actual time to solve the problem since Canvas records the time from when the problem is first accessed until the problem is submitted.

Figure 1 shows the number of attempts at solving the first problem on the first homework. The problem consisted of calculating the mole fraction of the atoms in stainless steel given the weight fractions of each of the components. A similar problem was demonstrated during the lecture. A full description of implementing the homework problems in Canvas is provided in the *Implementation* section, but briefly, the students were allowed four attempts to solve the problem, but each attempt generated a different set of weight fractions for the

components. The number of attempts was limited to four to prevent the students from randomly guessing the answer until getting it correct. Therefore the conceptual problem was the same in each attempt (how to convert weight fractions of components to mole fractions) but the specific values of the weight fractions were different in each attempt. In this case, 34 students (44%) solved the problem on the first attempt, 28 students (36%) of the students solved the problem after two attempts, 9 students (12%) solved the problem after 3 attempts, and 1 student solved the problem after four attempts. Three students got the wrong answer and gave up after the first attempt, one student gave up after two attempts, and two students used all four attempts but did not obtain the correct answer. This data is summarized in Table 2 along with data for a much more difficult homework problem from an assignment at the end of the semester. The second homework problem was a corrosion problem that the students had not encountered before (no similar example in the class) and required some original thought and attention to detail.

Table 2. Attempts at solving problems in online homework.

Attempts at solving the problem	**Homework Ex. 1 (easy)**		**Homework Ex. 2 (difficult)**	
	Number of Students	**Percentage of Students**	**Number of Students**	**Percentage of Students**
Solved problem on first attempt	34	43.6%	23	29.5%
Solved problem on second attempt	28	35.9%	14	17.9%
Solved problem on third attempt	9	11.5%	7	9.0%
Solved problem on fourth attempt	1	1.3%	5	6.4%
Gave up after 1st attempt	3	3.8%	11	14.1%
Gave up after 2nd attempt	1	1.3%	2	2.6%
Gave up after 3rd attempt	0	0	2	2.6%
Could not solve after four attempts	2	2.6%	9	11.5%
Did not attempt the problem	0	0	5	6.4%

Figure 1. Bar charts showing the student's persistence in doing the online homework (Y-axis is the number students, the X-axis is the number of attempts the student used)

The traditional paper-based homework has, by definition, one attempt to solve the problem. The student does not receive feedback on if the problem is correct or incorrect for typically one week after the assignment is turned in. However, each student will have the identical problem, with the same numeric values. Therefore, students can compare answers before submitting the assignment and possibly correct their mistakes. Table 3 shows the submission rate and the correctness for the same easy and difficult problems shown in Table 2.

Table 3. Submissions and Correctness of an easy and difficult problem

	Easy Problem		**Hard Problem**	
	Traditional HW	Online HW	Traditional HW	Online HW
Percent Correct	91%	92.3%	23%	62.8%
Failed to submit	0%	0%	13%	6.4%

Out of the 77 students that missed the difficult problem for traditional paper-based homework, 31 of the students had made the same mistake. With the paper homework, there is no immediate feedback when the problem is wrong, and the students believed they had completed the problem correctly and may have encouraged their friends to solve the problem incorrectly as well. With the online homework, the students were made aware of their mistake and had the opportunity to correct their work, although with a different set of values in the problem statement.

Comparing the students' performance on the homework is difficult since the online homework provides immediate feedback about the correctness of the answer and allows the student to retry the problem in the case of incorrect answers for over half of the assigned problems. This is not the case for paper homework, where all feedback is postponed until after the assignment is graded by the instructor. However, the performance on the exams can give an indication of the effectiveness of the two homework styles. A comparison of the homework performance to exam performance is shown in Figure 2. The final exam score was used to evaluate the performance since the exam is the same between the two semesters. The other two exams during the semester have necessarily different questions since the exams are returned to the students. As can be seen in Figure 2 the performance of students doing online homework is shifted towards better scores on the exam. The final exam is not cumulative and only covers the last third of the course. Table 4 shows the correlation coefficient between the homework performance and the final exam performance. The correlation is evaluated for all homework assignments (overall) and performance on the homework assignments focused on the topics covered in the final exam (topics). As can be seen, there is a much stronger correlation between the online homework performance and performing well on the final exam. In this particular class, the homework is not reviewed during the regular lecture time. Therefore, using Canvas based homework does not free up additional time during the lecture, however, if it is the instructor's general practice is to spend significant time reviewing and solving the homework during class, the Canvas based homework may free up additional time for the lecture. In general, the quantitative analysis strongly supports adopting an online homework model.

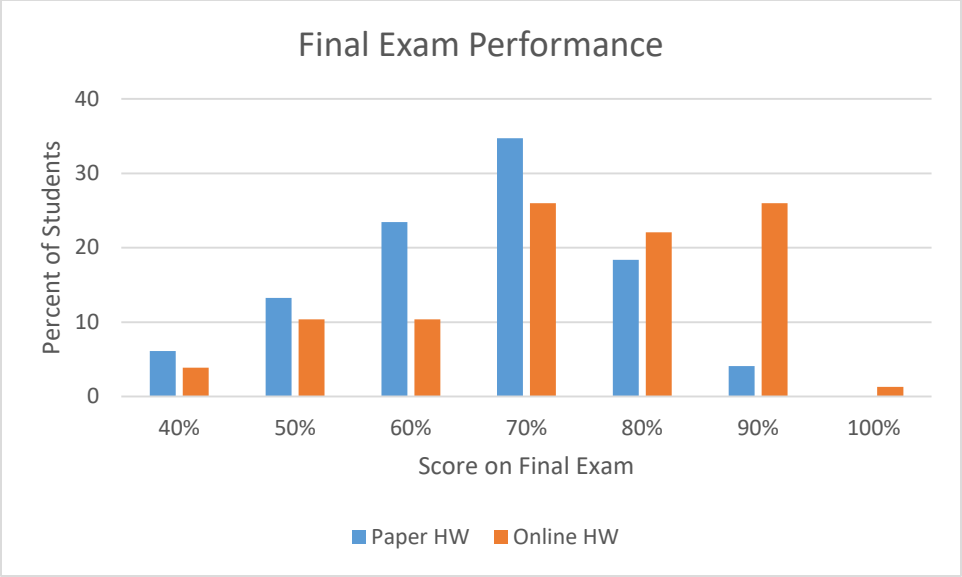

Figure 2. Performance on the final exam based on homework type.

Table 4. Correlation Coefficient between homework performance and Final exam score

Homework	**Final Exam Correlation Coefficient**
Overall Paper-based homework	0.263
Topics Paper-based homework	0.189
Overall Online Homework	0.533
Topics Online Homework	0.487

Qualitative Analysis

The students' perceptions of the online homework were obtained through a Likert scale questionnaire that included three open response questions. The questionnaire focused on seven different categories pertaining to the online homework which included the following: time spent on the homework, the relevance of the homework, if the students worked on the homework in teams, persistence in accomplishing the homework, multiple attempts to solve a problem, comfort with using online homework and finally the type of homework questions. The survey questions were not grouped together but randomly distributed in the survey. The responses, except for the three open-ended questions, used a 5-point scale with the following descriptions. 5 – Strongly agree, 4 – agree, 3 – Neither Agree or Disagree, 2 – Disagree, 1 – Strongly Disagree. The following tables list the survey question, average response and standard deviation in each category. A total of 75 responses were received for this questionnaire.

Table 5. Survey questions about time spent on online homework

Time Spent on Homework	Average	Standard Deviation
I spent more time working on online homework than I would have spent working on traditional paper and pencil assignments.	3.0	1.0
I believe that there should have been less homework assignments.	2.9	1.0
I believe that there should have been more homework assignments.	2.2	0.8

As can be seen in this Table 5, the students believed that the time spent on online homework was roughly equivalent to the time they would have spent using paper homework and that the number of assignments was approximately correct.

Table 6. Questions related to allowing multiple attempts to solve a problem in online homework

Multiple Attempts to Solve a Problem	Average	Standard Deviation
If I completed a problem incorrectly, I retried the problem starting from the beginning.	4.0	0.7
I think the hints on how to solve the problem that were displayed when I submitted a wrong answer helped in obtaining the correct answer in subsequent attempts.	3.4	1.2
I think that 4 attempts for a problem was too few, there should be more attempts allowed.	3.2	1.1
I think 4 attempts for a problem is too many, I think fewer attempts should be allowed.	1.6	0.7
Seeing the correct answer when I did a problem wrong helped me understand what I did wrong.	4.3	0.9
The online homework assignments were challenging.	3.9	0.7
If I completed a problem incorrectly, I used the correct answer to work backwards to determine the correct answer.	4.1	1.1

The numeric problems allowed the students up to four attempts to solve the problem. Each attempt used different values for the variables in the problem. The correct answer was provided after the student submitted an answer. Four attempts to solve a problem seems the correct amount. Overwhelmingly the students indicated that less than four attempts would be too few and the data shown in Figure 1 indicates that a few students actually used all four attempts. One unintended consequence of allowing multiple attempts is the students using the correct answer to work the problem in reverse to determine where their mistake is. While this does not seem to detract from their exam performance, it may not be as useful as resolving the problem from the beginning. However, since the values of the variables change, after finding their mistake, the problem would have to be resolved with the new values.

Table 7. Survey questions about persistence in doing the online homework

Persistence	Average	Standard Deviation
I completed all of the online homework assignments.	4.0	1.1
If I completed a problem incorrectly, I gave up and did not try the problem again.	1.6	0.8
I never tried to figure out my mistakes on a question I answered wrong.	1.9	1.1
Using online homework encouraged me to be more consistent in doing homework.	3.6	1.0

Table 8. Survey questions about the relevance of the online homework

Relevance	Average	Standard Deviation
The online homework assignments were relevant to what was presented during lecture.	4.2	0.7
The online homework assignments were a waste of time.	2	1.0
The online homework did not further my understanding of materials concepts	2.1	1.0
The online homework assignments made me think more about materials than I would have otherwise.	3.5	1.0
I only completed the online homework assignments because they were worth a portion of my grade.	3.1	1.3
I would have completed the online homework assignments even if they were not graded.	2.9	1.2

Table 9. Survey questions about teamwork while doing online homework.

Teamwork	Average	Standard Deviation
I worked alone to solve all of the homework problems.	3.5	1.1
I could complete the homework assignments with little outside help.	3.4	1.0
I worked in a group to solve homework problems.	2.6	1.2

The online homework does not encourage teamwork when solving homework problems. This is because each student is given a random set of values for the variables in the problem, so they cannot share answers. However, each student is given the same problem, so they can work together to create a solution method and then each student could use that method to solve their own problem. It would be possible to have the homework problem pulled randomly from a bank of questions, giving each student a different version of a similar problem to prevent teamwork. It is also possible to create groups in Canvas and assign a single problem to the group to encourage teamwork.

Table 10. Survey questions about the student comfort with using online homework

Comfort with Online Homework	Average	Standard Deviation
In the future I would avoid a course that included online homework.	2.3	0.9
Using online homework was more convenient than pencil and paper homework assignments.	3.6	1.2
I would recommend other courses use online homework.	3.5	1.1
Overall, my experience with online homework was positive.	4.0	0.8
I had technical difficulties (problems accessing Canvas, etc.) when attempting the online homework.	2.1	1.1
I would recommend friends take courses with online homework versus regular pencil and paper homework	3.4	1.0

Table 11. Survey questions about the type of problems in the online homework

Type of Problems	Average	Standard Deviation
I think there should have been more numerical problems and less open ended text entry problems.	3.1	0.8
I think there should have been more open ended - text entry - problems and less numerical problems.	2.6	0.8
The online homework encouraged me to do less cramming for the exam than traditional paper and pencil assignments.	3.1	1.1

Implementation

The homework assignments were administered through Canvas learning management system using the Quiz feature. The quiz feature allows multiple types of quiz questions, including the following: multiple choice, true/false, (text) fill in the blank, fill in multiple blanks, multiple answers, multiple dropdowns, matching, numerical answer, formula question, essay question, and file upload questions. The specific distribution of the Canvas system at an institution can be slightly different, so all of these choices may or may not be available. The main types of questions that were used in the homework assignments in this study included formula questions, essay questions, and file upload questions. Of the 112 online problems, 61 problems were formula problems, 45 were text entry problems and 6 were file upload problems.

Formula questions allow the instructor to create a problem statement with variables. When the problem statement is accessed by the student the variables are replaced with randomly generated values within a range specified by the instructor. Each variable can have a unique allowable range and significant digits. An equation for the solution to the problem that uses the variables is defined by the instructor and used to validate the student's answer. Each time the problem is presented to the student, the values of the variables are randomly generated. The

students are required to type their answer into the dialog box provided by Canvas. After the student submits an answer, it is possible to display messages based on whether the student got the answer correct or not. Hints on how to solve the problem can be provided to the student using this mechanism. If the student solved the problem incorrectly, the correct answer can be shown to the student as well as the hint and the student can retry the problem with all new values for the variables in the problem. The hint, if provided, is text that the instructor has written to help the student solve the problem. For example, “Don’t forget to use absolute temperature when using the universal gas constant” or similar suggestions based on common errors the students make when solving the problem. The instructor can choose the number of attempts the student can have to solve the problem.

The essay and file upload questions are used for problems that do not have a numerical answer. The essay question type provides a text box for the student to type in the answer and is used for questions that require only text entry. The file upload question type is used for problems that require charts or graphical answers. In this case, the student scans the solution and uploads the scanned file. Both of these types of questions need to be graded by the instructor and do not provide immediate feedback. Figure 3a, 3b, and 3c show examples of the three types of questions.

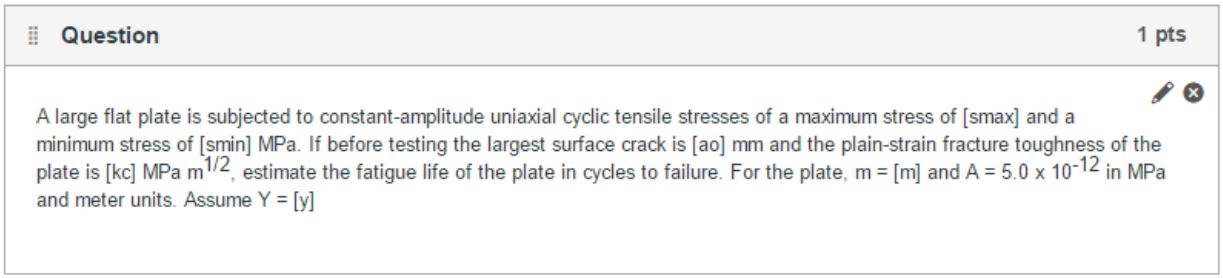

Figure 3a. An example of a Formula type question. The text inside of the square brackets are variables that are changed by Canvas every time the problem is accessed by a student. The student is provided a text box for typing their answers.

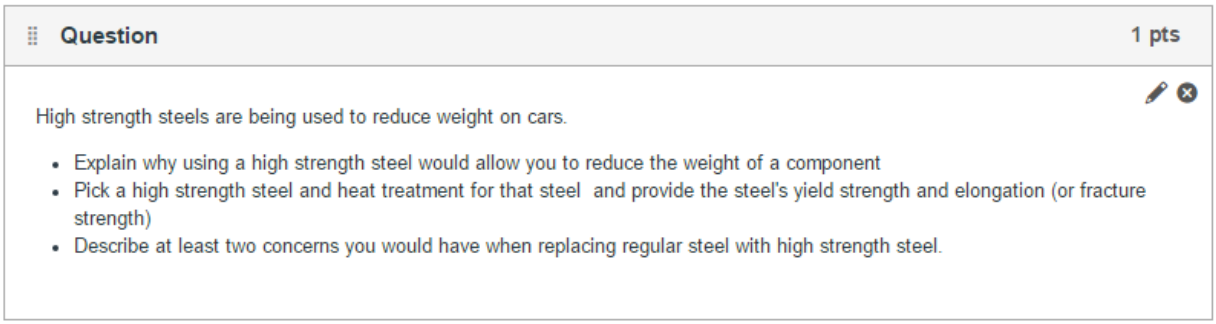

Figure 3b. An example of an essay question. The student is provided a text box to type in the answer.

Question 1 pts

1. The following eneingeering stress-strain data were obtained at the beginning of a tensile test for 0.2% C plain-carbon steel. (a) Plot the engineering stress-strain curve for these data. (b) Determine the 0.2 percent offset yield stress for this steel. (c) Determine the tensile elastic modulus of this steel.

1. Engineering Stress (ksi)	Engineering Strain (in./in.)
0	0
15	.0005
30	.001
40	.0015
50	.002
60	.0035
66	.004
70	.006
72	.008

Figure 3c. A file-upload question. The student must scan in their work and upload the file as a pdf for grading.

There are significant logistical advantages to using Canvas to administer the homework. The difficulty of transporting and tracking paper-based assignments is alleviated. This is especially useful if the class has a grader helping to grade the homework. The student submits the assignment electronically, there is a time-stamp on the submission and the submission is stored as long as the Canvas site is available. Students that miss class can still submit the homework, even if they are traveling. This not only saves time in the class since the instructor does not need to hand back papers but also helps prevent unintentional FERPA violations if the process of handing around a stack of homework is the chosen method of returning homework to the students.

There are some limitations to using Canvas for the homework assignments when using the formula question type. The largest limitation is that it is not possible to review the student's process/work in solving a problem or assign partial credit. In addition, it is not possible to ask multiple questions about a randomly generated set of data. Each question can only have one

answer. For example, if a set of data points are randomly generated, it is possible to ask what is the mean of the data points, however, it is not possible to ask what is the mean and standard deviation of the same data set. Of course, a standard deviation question could be asked in a separate problem with a different set of data. Another limitation is that intermediate calculations on the variables are not possible. This makes it difficult to randomly generate a set of data that sums to a specific value. For example, it is impossible to create randomly generated weight fractions of elements that sum to 100%. This particular problem was overcome by randomly generating values for all but one of the components and then stating that the remainder of the weight was the final component. Canvas will only use one equation when calculating the correct answer. This has not been a significant problem since all intermediate equations can be combined into a single equation, but it does lead to some very long and complicated single equation solutions.

The following are specific recommendations for the implementation of online homework. If the student is going to be able to attempt the homework problem multiple times it is best to make that problem an individual quiz. While it seems easier to create a single quiz with multiple problems in the quiz for an assignment, if multiple attempts are allowed, the student will have to redo every problem on the quiz, including the problems that were answered correctly. Creating a separate quiz for each problem allows the student to just reattempt the problem that was missed. Canvas will compare the student's answer to the numerically generated answer based on the solution equation. It is very important that the instructor and the students use the same values for any constants used in the equations. A good practice is to provide a list of constants to be used in the class when solving problems since the solution can be slightly different depending on the value of the constant used, i.e. using $\pi = 3.141$ is not the same as $\pi = 3.14159265$. The last sentence of the problem statement should indicate the units expected and the level of accuracy (number of digits after the decimal point) expected for the answer. Canvas will not count 12.0 inches or 1.001 feet as being correct if the "correct" answer of 1.0 feet. Finally, it is very important to make sure the solution equation is correct before giving the assignment to the students. While no questions were graded incorrectly in this study, previous experience has shown that if the solution equation is wrong due to a misplaced decimal or a transposed value for a constant, then when the student is doing the problem correctly Canvas will mark the problem as wrong and provide the student with the wrong answer. This leads to student confusion as well as significant work to fix mis-graded homework assignments.

Conclusion

Using the Canvas based online homework resulted in higher scores on exams and more consistent completion of the homework as well as a higher correlation between homework scores and exam scores. This can be attributed to the immediate feedback on the correctness of the problem as well as allowing multiple attempts to solve the problem. In addition, students persisted with completing and submitting homework more consistently when using the online homework. The attitude of the students towards online homework was evaluated in seven different categories and in all categories the online homework was equivalent or considered better to paper-based homework by most students. Automatic grading of numeric problems as

well as removing some of the logistical requirements of collecting and returning homework assignments reduces the time commitment and difficulty in teaching large classes.

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