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Feasibility of graded, electronic homework assignments in a second year chemical engineering course

Ms. Ann Kowalski, Colorado State University

I am a Ph.D. student in Chemical and Biological Engineering at Colorado State University. I received by B.S. in Biosystems Engineering from Clemson University in 2012. My research focuses on the synthesis and characterization of metal nanostructures within three-dimensional protein crystal scaffolds. Additionally, I have experience as a teaching assistant in a variety of undergraduate engineering courses. Through a Graduate Teaching Fellowship, I have been involved in education research within the College of Engineering at CSU.

Prof. Christopher Snow Snow

Dr. Snow joined the Chemical and Biological Engineering department at Colorado State University in 2011.

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Introduction

Larger undergraduate class sizes have led to an increased workload for graders, teaching assistants, and professors.[1,2] Homework grading comprises much of this work.[3] One solution in the Department of Chemical and Biological Engineering at Colorado State University has been to grade only a subset of problems from each assignment. Yet turnaround time has remained lengthy and beneficial feedback is infrequent, as graders are not often meaningfully involved in the course. In other cases, professors assign but do not collect homework.[3] However, in some cases it has been shown that learning is hindered without graded homework.[4]

Web-based tools for developing interactive assignments have improved significantly in recent years, and many universities have begun to experiment with assigning homework online. The effectiveness of online assignments has been studied in college courses ranging from general chemistry[5] and math[2,6], to sociology[7] and microeconomics[8]. In most cases, the results suggest that students view these online system favorably[1,5,6,9] and there is either increased course comprehension[1,4,6] or no significant change to exam scores.[3] Few studies can be found examining an online homework system in large engineering courses,[10] perhaps because engineering homework requires complex problem solving that is difficult to distill into an online format (e.g. an entire assignment may consist of only one problem).

We used a web-based tool (Canvas Learning Management System[11] by Instructure) to convert the homework assignments for a 200-level chemical engineering course to an online, graded format. We compared exam scores between this year and the past five years, analyzed the time savings for professors and graders, and distributed a Likert scale survey to determine the students' view of the online homework system. Results showed that the students had an overall favorable view of the online homework system and overall exams scores were not negatively impacted by this new method. We will use this data to improve the assignments, make suggestions for future users, and potentially expand this method to other undergraduate engineering courses.

Methods

The subject of this study was a 200-level course titled Material and Energy Balances within the Department of Chemical and Biological Engineering (CBE) at Colorado State University. The course consisted of one section of 126 students. Each of the eight homework assignments throughout the semester was converted to a set of assignments within the Canvas Learning Management System by Instructure, which is widely used throughout Colorado State University. All students had experience navigating Canvas in previous courses, but may not have used this system for assignments or quizzes in the past.

Unlike paper homework, these online homeworks guided students through the problem solving process, providing feedback along the way. In this way, students could receive partial credit for the overall problem by answering sub-questions correctly. For example, a typical homework included questions that asked students to identify the correct process flow diagram, complete a degree of freedom analysis, and write material or energy balances before proceeding to solve. (Several example homework questions are included at the end of this document.)

After the assignment, the students could immediately view questions they missed and send comments directly to the professor. Approximately half of all homework questions allowed two attempts, of which the higher score was taken, while the other half only allowed one attempt. Students knew how many attempts they had before beginning each homework. No assignments had time limits, but each had four slightly different versions to encourage academic integrity. Manual grading was only required on several occasions when students uploaded MATLAB scripts and/or plots.

The success of this online homework system was measured by comparing exam scores to the previous five years and by a Likert scale student opinion survey, which was optional and anonymous. For the past five years, the course was taught by the same instructor using exam questions drawn from a common pool; however, the students were given paper homework assignments in past years instead of online Canvas homework.

Results

Exam scores

Exam score data was collected from 2012 to 2017 (the study year). Figure 1 shows the median exam scores from exam 1, exam 2, and the final exam for each year. Median exam 1 and 2 scores were the highest for the study year (2017) when compared to previous years, but the final exam score was not. As is typical in STEM courses, the final exam is cumulative in the sense that it builds off knowledge obtained throughout the entire semester.

We used a Welch's t-test for unequal sample sizes and unequal variances, and found a $t_{critical}$ of 1.96 with a p-value of 0.05 and a normal distribution (large sample size). We analyzed the mean exam scores from the control years (2012 – 2016) and the study year (2017) and found that the exam 1 and exam 2 scores from 2017 were significantly higher than those of the control years ($p < 0.05$), but the final exam scores were not significantly different (Table 1).

Additionally, standard deviations of exam scores remain consistent throughout the sample years (between 14 and 25 points) and all exam histograms showed scores slightly skewed towards low values (data not shown).

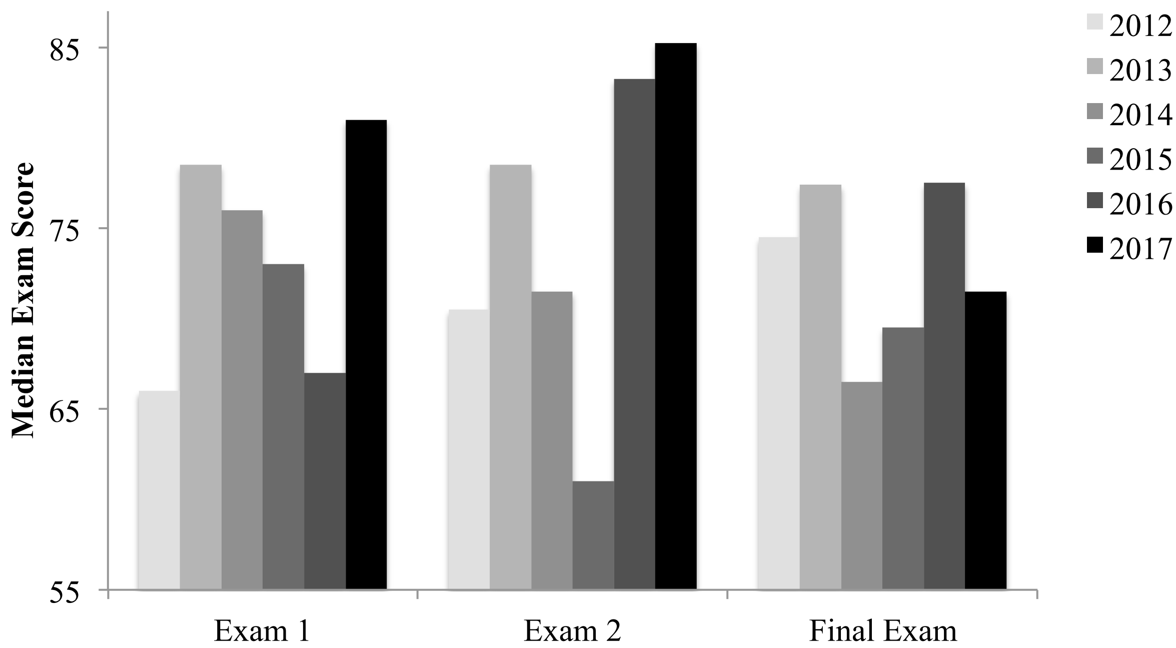

Figure 1. Median exam scores from 2012 to 2017.

Table 1. Exam score comparison between control years and experimental year.

	Exam 1		Exam 2		Final Exam	
	Control Group (2012 - 2016)	Experimental Group (2017)	Control Group (2012 - 2016)	Experimental Group (2017)	Control Group (2012 - 2016)	Experimental Group (2017)
Mean	69.3	77.1	70	81.3	70	68.4
Standard Deviation	18.4	16.6	19.3	14	19.3	20.4
Number of Samples	494	126	494	126	494	126
t-value		4.6		7.4		0.8

Student opinion survey

During the last week of the semester, a Likert scale survey was made available on Canvas for all students. Completion of the survey was incentivized with the value of 1/3 of a homework assignment. The survey was completed by 118 of the 126 registered students. The fifteen question survey asked students to evaluate a variety of aspects of the Canvas homework assignments.

Approximately 60% of students responded ‘yes’ when asked if the format of the Canvas homework assignments was easy to understand, with an additional 25% answering ‘somewhat.’

Unsurprisingly, 92% of students preferred homework questions that allowed two attempts rather than one. 95% of students believed the Canvas homework helped them understand the course material, while 80% believed the Canvas homework questions were applicable to the exams and 69% stated that the Canvas homework at least somewhat helped them prepare for exams (Fig. 2).

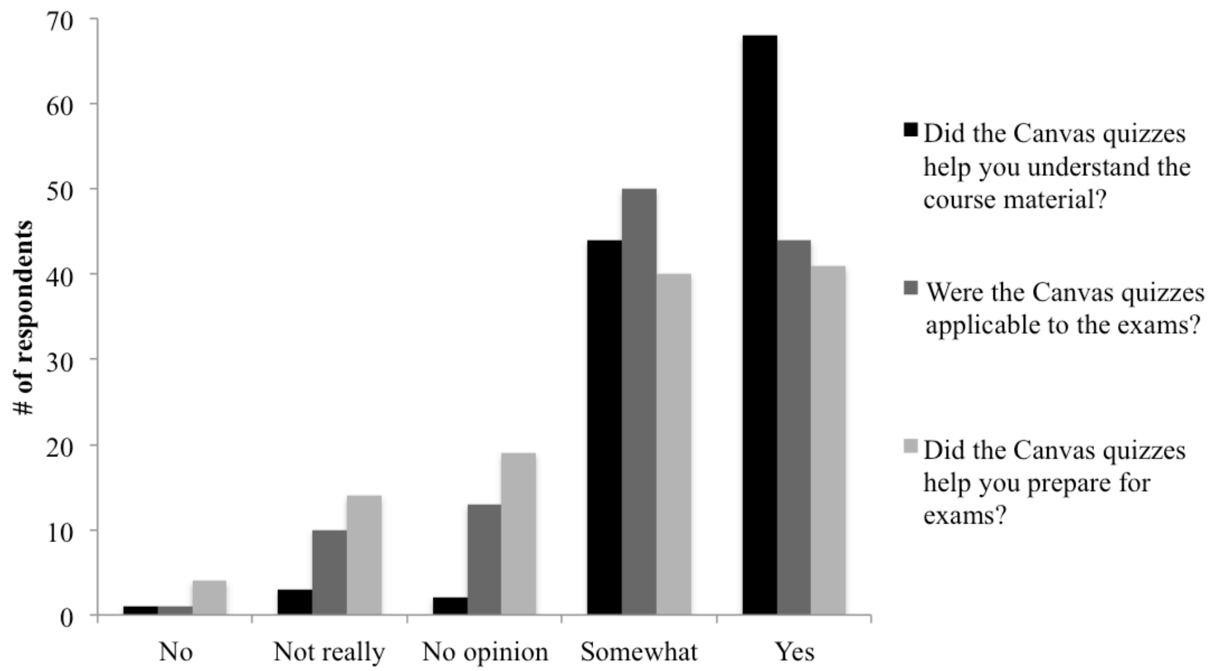

Figure 2. Survey questions related to course comprehension through Canvas homeworks.

With regards to Canvas homework automated grading, 86% of students thought the grading was at least somewhat fair, while only 5% of students believed it was 'not' or 'not really' fair. Additionally, 38% of students thought the point values assigned to the Canvas homework questions were 'somewhat' representative of the question difficulty and effort required, while an additional 37% thought the point values were fully representative.

On a related note, 42% of students answered 'yes' and 30% answered 'somewhat' when asked if they believed each Canvas homework assignment contained enough opportunity for partial credit. In fact, 31% of students believed the Canvas homework assignments should be worth a larger percent of their course grade, while only 8% believed they should be worth a smaller percent of the course grade (Table 2). Homework is currently worth 16% of the total course grade, with exams, group projects, and attendance making up the remainder.

Table 2. Survey questions related to the grading of Canvas homeworks.

	Were the point values representative of the question difficulty and/or effort required?	Was the grading fair on the Canvas quizzes?	Should the Canvas quizzes be worth a smaller percentage of your overall grade?	Should the Canvas quizzes be worth a higher percentage of your overall grade?
No	1	1	**57**	17
Not really	11	5	22	15
No opinion	17	10	21	**32**
Somewhat	**45**	**47**	8	17
Yes	**44**	**55**	10	**37**

Several survey questions asked students to compare their view of the Canvas homework system with their past experiences completing traditional paper homework. For example, 41% of students stated that they preferred the Canvas assignments over paper homework, while only 16% preferred the paper homework. Despite this, students were split when asked if they learned more by completing paper homework over online Canvas homework. Half of the students answered 'no' or 'not really' when asked if they learned more by completing paper homework. One quarter had no opinion, and the last quarter answered 'somewhat' or 'yes.' Finally, 25% of students answered 'no' or 'not really', while 63% answered 'somewhat' or 'yes', when asked if they believed more large engineering courses should use Canvas homework in lieu of traditional paper homework assignments (Fig. 3).

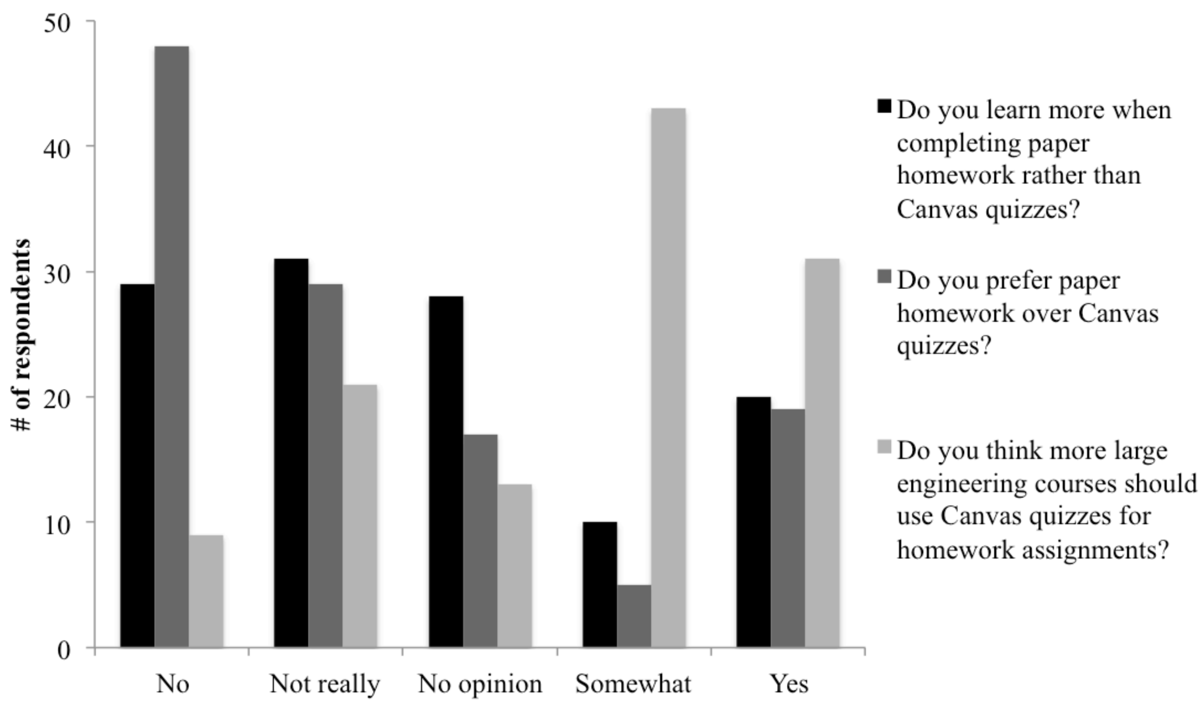

Figure 3. Analysis of survey questions which asked students to compare the Canvas homework to traditional paper homework assignments.

Discussion

Although the online homework format did not have an overall detrimental effect on student exam scores and in two cases (exam 1 and exam 2) the scores from 2017 were significantly higher than past years, we cannot say whether it may improve comprehension. Several variables changed over the years while exam scores were collected (e.g. acceptance rates to the engineering program at CSU became lower, presumably the professor improved teaching strategies as a result of previous years' feedback, and although pulled from a common pool, exam questions were different each year). Additionally, exam grading was not completely objective. Partial credit can be given on the subjective basis of the grader, and the assigned grader changes from year to year.

As far as student opinion, most comments were in regards to the bugs associated with the new system, not with the system itself. Overall, students preferred the online method because it 1) walked them through the problem solving process, 2) allowed multiple attempts, 3) gave instant feedback, and 4) kept all documents associated with the course in one organized location. The most common suggestions were to 1) incorporate more feedback, hints, and comments on incorrect responses, 2) include more robust margins of error within answers, and 3) add as many sub-questions as possible to maximize partial credit.

Several students who preferred paper homework over online homework reasoned that the Canvas homework forced them to solve the problem in a specific way they may not have chosen on an exam, and that the online homework became confusing when they began to solve the sub-questions; they lost sight of the overall goal of the problem. In this case, we suggest that the whole problem statement is always written at the top of an online homework assignment, so that students can choose to solve the problem in its entirety by hand before inputting any electronic responses.

The authors recommend that future users not make multiple versions of online homework assignments. These versions were the source of the vast majority of errors in the system and did not prevent any cooperation among students. Instead, it is recommended to include a statement of academic integrity requiring an electronic signature at the end of each assignment. With the mindset that it's acceptable for students to collaborate, time can instead be used to include more partial credit opportunities and incorporate more meaningful feedback into the system (e.g. by choosing specific incorrect answer options that allow for explanation and learning).

A significant benefit attributed to online, automatically-graded assignments is the time savings for professors, graders, and teaching assistants. We approximate that 80-100 hours were spent creating the homework assignments for the semester in Canvas. This included making four versions of each homework problem. Grader assignments typically range from 10 to 15 hours per week. This year, grading was completed in <1 hour per week, which consisted of checking statements of academic integrity and any MATLAB scripts or plots that were uploaded. This is a time savings of at least 50 hours over the semester, and we hypothesize that time spent editing the assignments will drop significantly in future semesters.

A second benefit to online, automatically-graded assignments is increased consistency in grading. More objective grading can be accomplished with this system while still allowing for partial credit. This helps negate the effect of grader fatigue and varying grader opinion.

Conclusions

In conclusion, we have created a fully automated, interactive method for homework assignments within the Canvas Learning Management System. This method was received positively by students and the time saving for graders was considerable. Exams scores were not lower than previous years, and in some cases were significantly higher. The vast majority of students preferred the online homework system over traditional paper-and-pencil homework and the majority believe this system should be expanded to other large undergraduate courses within the College of Engineering.

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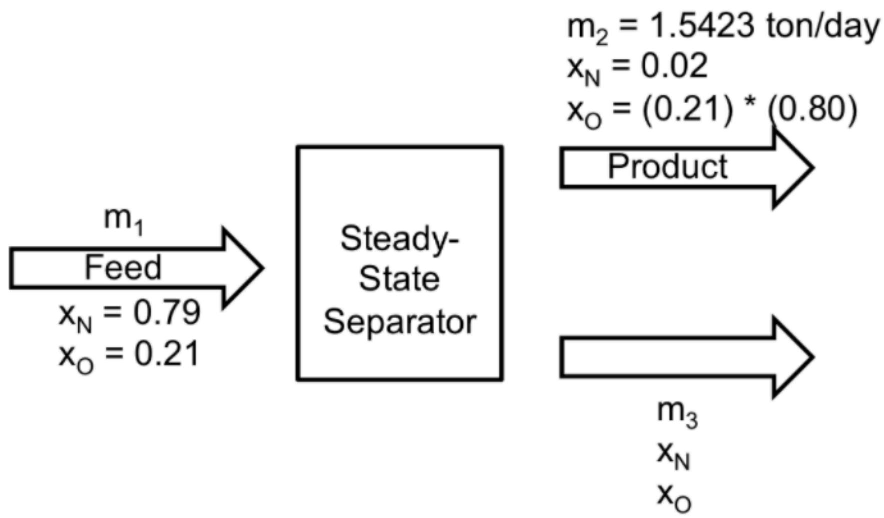
Example Canvas Homework Assignment

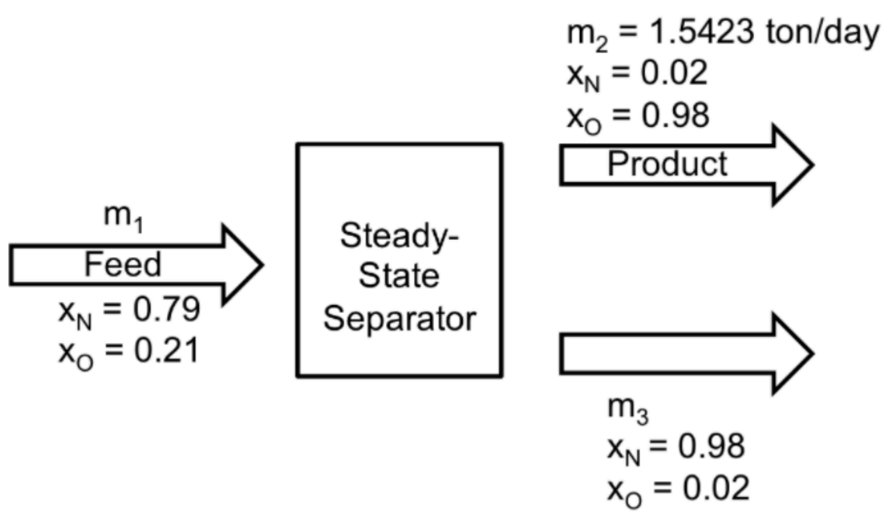
Quiz Instructions

Air, containing 79 mol% nitrogen (N_2) and 21 mol% oxygen (O_2), is split into two product streams by a separator operating at steady state. One product stream is 98 mol% O_2 and contains 80% of the oxygen in the air fed to the separator. The other stream is mostly nitrogen. You must produce 1.543 ton/day of the enriched oxygen product stream.

Question 1 1 pts

Which of the following diagrams most accurately represents the problem statement?





*** Two further options not shown**

Question 2

2 pts

Using the Murphy counting scheme, fill in the following DOF table by selecting the correct value from each dropdown:

IStrV	[Select]
ISysV	[Select]
Var	[Select]
SF	[Select]
SC	[Select]
Aux	[Select]
MB	[Select]
DOF	[Select]

Question 3

1 pts

Why aren't there any independent system variables (ISysV)?

Check all that apply.

- ☐ No material accumulates in the separator.
- ☐ The product flow rate is already specified.
- ☐ There are no reactions in the separator.
- ☐ There are only two components in each stream.
- ☐ The separator is operating at steady state.
- ☐ There is one unique solution to the problem.

Question 4

4 pts

Some information in the problem statement is given in mass quantities (e.g. ton/day), and some is given in mole fractions (e.g. mol%). Let's convert all the information we have to mass fractions, using a basis of 100 gmol. Match the variables in the following table with their corresponding value:

	x_i	[gmol]	[g/gmol]	[g]	w_i
Feed N_2	0.79	79	A	B	C
Feed O_2	0.21	21	D	E	F
Product N_2	0.02	2	G	H	I
Product O_2	0.98	98	J	K	L

A [Choose]

B [Choose]

C [Choose]

D [Choose]

E [Choose]

F [Choose]

G [Choose]

H [Choose]

I [Choose]

J [Choose]

K [Choose]

L [Choose]

Question 5

3 pts

Now, pick the correct value from each dropdown that completes the auxiliary equation:

"The product stream contains 80% of the oxygen in the air fed to the separator"

AKA

"(O_2 in stream 2) = 0.8 * (O_2 in stream 1)"

[Select] * [Select] ton/day = 0.8 *

[Select] * m_1

Question 6

1 pts

What is the mass flow rate in ton/day of the feed stream (m_1)?

Round to the nearest hundredth

Question 7

1 pts

What is the mass flow rate in ton/day of the nitrogen-rich product stream (m_3)?

Round to the nearest hundredth.

Question 8

3 pts

Complete the nitrogen mass balance by selecting the correct value from each dropdown:

0 = [Select] * 8.13 ton/day - 0.0175 * [Select] ton/day - $w_{N,3}$ * [Select]

Question 9

1 pts

What is the mol fraction N_2 in the nitrogen-rich product stream (stream 3)?

Keep answer as a decimal & round to the nearest hundredth.