Can I have More Problems to Practice? Student Usage and Course Success Related to Auto-graded, End-of-chapter Problems in a Material and Energy Balances Course

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Abstract

Online homework and interactive textbooks provide big data that can help address many questions about student engagement and learning. Auto-graded homework questions with randomized numbers and content can explore students' proficiency in course material. Using a fully interactive online textbook, Material and Energy Balances zyBook, success and attempts on homework questions are quantified. In past studies, students with an unlimited number of attempts completed a median of 94% correct over hundreds of questions. To provide students with more practice before exams, end-of-chapter problems were assigned. Students were only assigned a fraction of these summative, end-of-chapter problems. A single cohort of ~100 students generated data across 7 chapters before each of three midterm exams. Measuring if students correctly solved end-of-chapter problems beyond those required for a grade and if the extra practice helped their exam grades are central research themes. More specifically, several research questions will be explored: 1. What fraction of students correctly solve problems beyond those earning a homework grade? 2. Does the fraction of students completed extra problems and the number of extra problems successfully completed change over the course of the semester? 3. Since previous research found that success on homework problems increases with each letter grade, does completing more end-of-chapter questions than required correlate with higher exam grades?

Introduction

Human interactions are being measured using digital tools from smartphones to watches, which creates big data. Analyzing this type of data can improve products, lifestyles, and education, which is the focus here. Specifically, higher education transitioned quickly to online platforms, which may have included interactive textbooks, during the global pandemic in 2020.

Interactive textbooks encompass both active learning and big data. First, active pedagogies are generally evidence-based methods showing student success. However, faculty may feel adopting a new teaching technology is a social change, which can lead to slower adoption [1, 2]. Most previous work shows 20 to 50% of higher education students read traditional textbooks, but interactive textbooks have measured as high at 99% median reading participation [3-8].

Accelerated by the shift in 2020 to remote instruction, students are expected to quickly master numerous digital platforms. Here, the focus is on online homework, which is common in math, chemistry, physics, and many introductory engineering courses. In general, online homework aligns with best practices in learning and several learning theories, including the use of visuals, immediate feedback, and scaffolding [9-13]. Research findings related to online homework are abundant in both science than engineering education [14-23]. Overall, online homework features multiple problem versions and attempts, which can benefit learning [24].

The first chemical engineering course centers on engineering problem solving based upon the conservation of mass and energy. The course is normally titled Mass and Energy Balances, and many contributions to the engineering education literature focus are available, e.g., [25-28]. The specific course of interest is secondary to the findings presented. Here, the analysis of end-of-chapter, summative problems will be explored.

Materials and Methods

A fully interactive textbook, Material and Energy Balances zyBook, has been used for a chemical engineering course at a public university for 5 years. The interactive content follows other textbooks for the course and is used within any HTML5 compliant web browser. Over 80 sections, 140 animations, and over 1300 clicks briefly quantify the interactivity. Over 600 online homework questions, or challenge activities, were available for the 2020 cohort. More specifically, the first seven chapters will be examined. Challenge activities are scored as correct or incorrect regardless of attempts, and challenge activities contributed 5% of a students' final course grade. A 15-question forgiveness factor (~3% of the assigned questions) was provided for the students' grades, however, fraction correct presented here includes all attempts without accounting for the forgiveness factor.

To provide students with more practice before each of the three midterm exams, end-of-chapter problems were assigned. Students earned a full grade for correctly answering only a percentage of the problems available. Students were given about one week to complete these problems before each exam. Midterm exams were taken in weeks 4, 9, and 13, with the final exam in week 15. End-of-chapter challenge activities are questions requiring multiple concepts from the chapter and likely many steps to solve. These summative problems can also encompass content from preceding chapters. In contrast, in-section challenge activities are present in most sections, consisting of 3 to 6 scaffolded, question levels. A student must answer an earlier question level before proceeding to the next question level. 266 in-section question levels were required to be completed before the third midterm exam and will be used as a comparison to end of chapter questions. Of total challenge activity questions, 19% encompass assigned end-of-chapter questions and the rest are in-section questions. All challenge activities have rolling numbers as well as changing content, thus, any question level can contain thousands of variations. Challenge activities have unlimited number of attempts without penalty. Examples of challenge activities were included in our previous papers [28, 29].

Table 1. Number of students and end-of-chapter challenge activity question levels required and available before each midterm exam.

	Exam 1	**Exam 2**	**Exam 3**	**Final**
Students (#)	100	92	90	89
Required questions (#)	24	24	13	-
Available questions (#)	55	56	56	-

The number of end-of-chapter questions varied for each exam with 20-40% of available questions being required for homework points (Table 1). Thus, fraction correct may be presented as a percent of the required or available questions. A total of 104 students were initially enrolled,

and 15 students did not complete the course. Between Exam 1 and 2, 8 students withdrew, which was the same time when the campus closed due to the COVID-19 pandemic. Analysis only encompasses students taking each midterm exam.

Some fraction correct data will be presented using box plots. Each box represents the middle 50% of data, including 1st quartile, median, and 3rd quartile. Using box plots, removes the effects of individual outliers that can skew average values. Average or mean values may also be included for added clarity of skewness. In correlating different data sets, hypothesis testing was conducted. Performing t-tests generated p values with statistically significance being considered when $p < 0.05$. Using t-tests is justifiable even with nonnormal distributions when $n > 20$ [28].

Results and Discussion

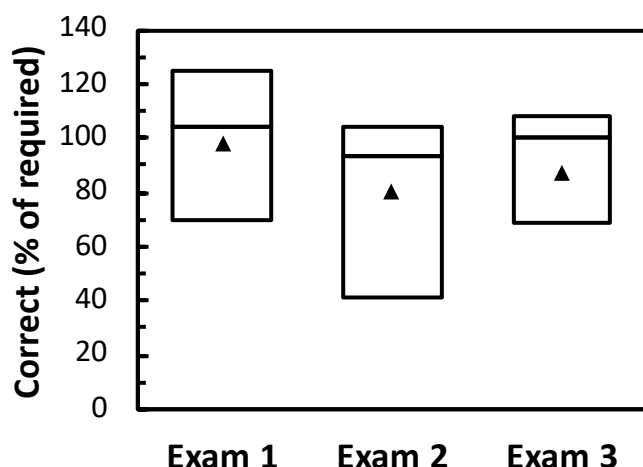<u>Do students correctly solve problems not originally assigned?</u>

Figure 1. Fraction correct of end-of-chapter challenge activities required before each midterm exam. Triangles represent mean.

Table 2. p values for fraction correct across exams presented in Figure 1.

Exam	1	2	3
1		0.018	0.17
2	0.018		0.34
3	0.17	0.34	

Students correctly solved end-of-chapter challenge activities assigned before each of the three midterm exams (Figure 1). Median fraction correct was consistently high with median correct of 104, 100, and 94% for Exams 1, 2, and 3, respectively. The 1st quartile correct was highest for Exam 1 (125%), and lowest for Exam 2 (104%). Challenge activities before Exam 1 showed the highest overall correct, which may be for several reasons. First, the course was still fully in-person at this point and attendance/engagement was very high. Also, Chapter 1 is primarily review from previous courses and included unit conversions, significant figures, and other general skills. The widest variation in correct is for Exam 2, which occurred two weeks after

Spring Break and coincided with the campus closure and shift to remote instruction. The dramatic improvement of the 3rd quartile correct between Exams 2 and 3 may indicate students becoming more comfortable with remote learning as well as some students withdrawing from participating entirely in the course. Overall, some students, 25 to more than 50%, correctly answered summative, end-of-chapter questions beyond the required amount before every exam.
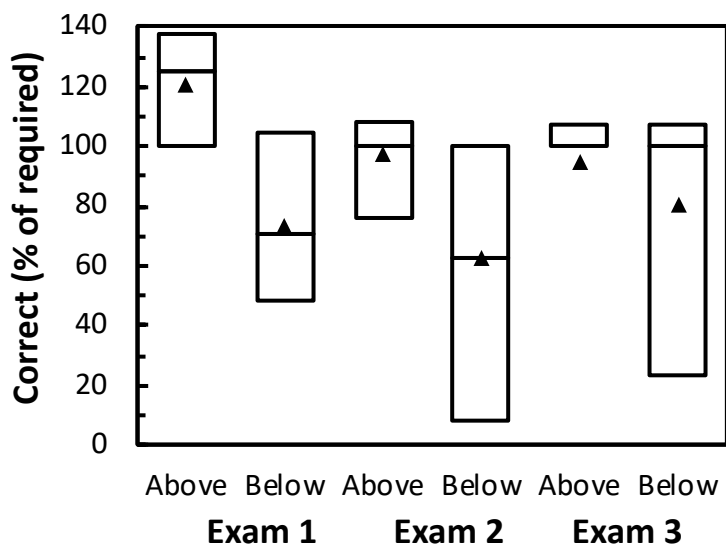

Figure 2. Fraction correct of end-of-chapter challenge activities required above and below median exam scores. Triangles represent mean. P values between above and below for each exam are < 0.001.

Generally, students who correctly completed more end-of-chapter challenge activities performed better on exams. By separating each exam cohort into students who fell above and below the median exam score, statistically significant differences in fraction correct were found (Figure 2). For students scoring above the median exam score, the median fraction correct on end-of-chapter challenge activities were all at least 100%, which confirms high engagement and preparation. For students below the exam median, median fraction correct varied, from 63 and 69% for the first two exams to 100% for Exam 3. Especially for Exams 2 and 3, the large deviations from median to 3rd quartile correct are noted, which indicates that half of the students scoring below the median exam score could not correctly answer or did not attempt a significant number of the end-of-chapter challenge activities.

Table 3. Percent of students above or below 100% correct of required challenge activites.

Correct (%)	Exam 1	Exam 2	Exam 3
>100	52	29	34
=100	7	20	30
<100	34	46	19
0	7	5	17

Of the students taking each exam, high fractions of students correctly completed at or above the assigned number of end-of-chapter problems (Table 3). Exam 3 showed the largest percentage of

students completing 100% or more of the required end-of-chapter challenge activities (64%), followed by Exam 1 (59%) and Exam 2 (49%). Interestingly, more than four times the percent of students completed *exactly* 100% for Exam 3 (30%) than Exam 1 (7%). This finding may be due to several factors, including screen fatigue from 100% remote learning or the length and difficulty of summative challenge activities for Exam 3. Questions involved both material and energy balances in all cases for Exam 3. Exam 3 also showed the largest percent of students not completing any challenge activities (17%). The percent of students completing more than required decreased across exams, while the percent of students completed exactly 100% increased. As the semester progressed, students tended to have more of an all or nothing mindset on end-of-chapter problems.

How does completing more than asked correlate to exam grades?
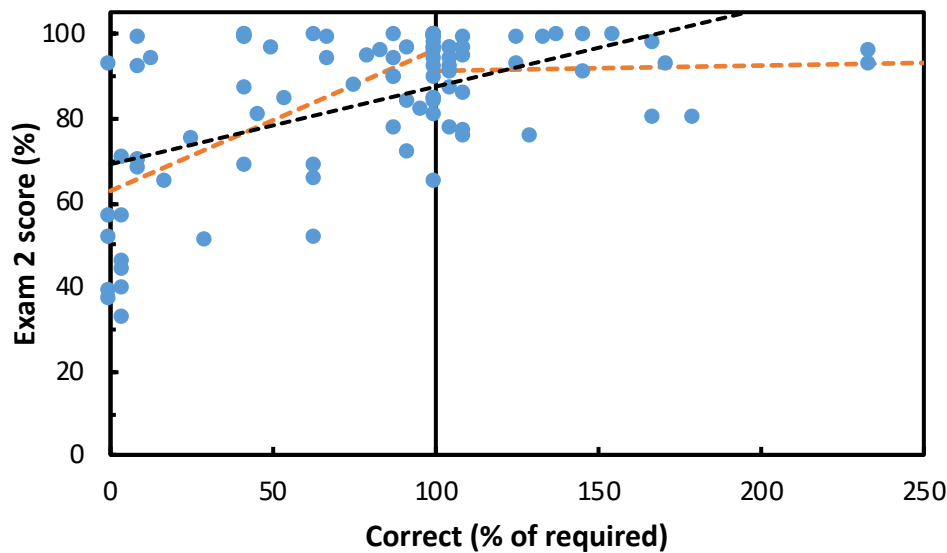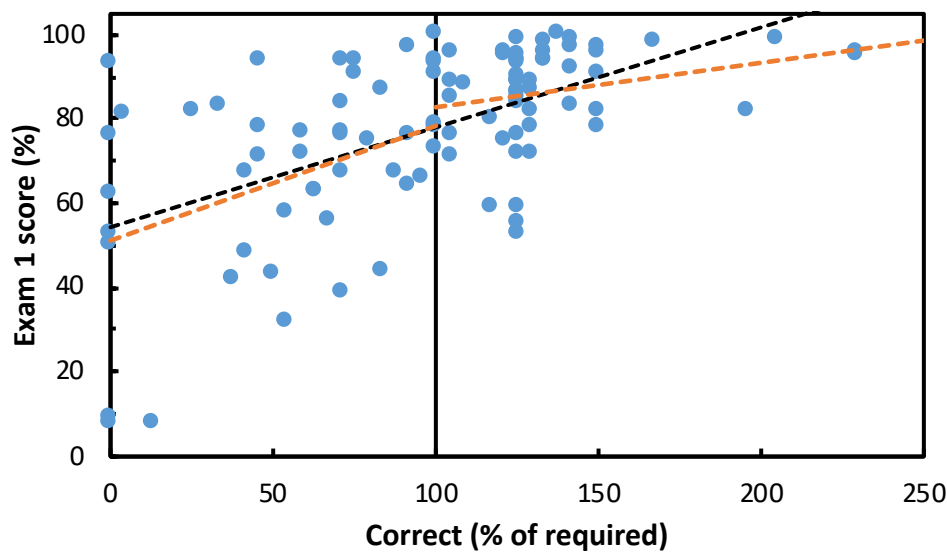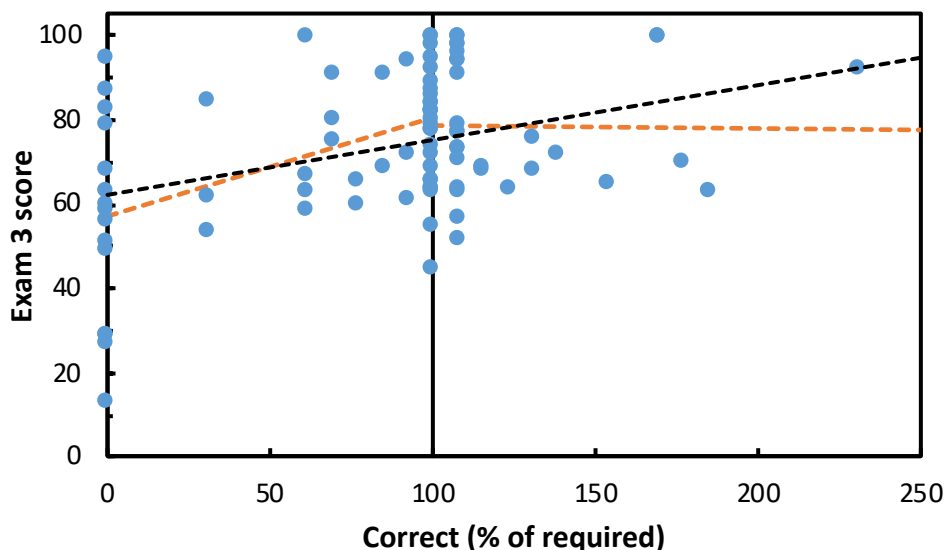
Figure 3. Exam score as a function of fraction end-of-chapter correct of challenge activities required.

Table 4. Slope and Pearson correlation coefficients for above and below 100% of required end-of-chapter challenge activities correctly completed for each midterm exams.

	Combined		<100%		≥100%	
	m	**R**	**m**	**R**	**m**	**R**
Exam 1	0.23	0.58	0.27	0.36	0.10	0.25
Exam 2	0.18	0.55	0.33	0.55	0.01	0.04
Exam 3	0.13	0.37	0.23	0.42	-0.005	0.01

Correctly completing more end-of-chapter challenge activities positively correlated with exam grades for all three midterm exams (Figure 3). Combining all students who took each exam, positive slopes were present as well as high Pearson coefficients (Table 4). Exam 1 resulted in the largest slope and largest Pearson coefficient, while Exam 3 resulted in both the lowest slope and Pearson coefficient. Overall, a positive correlation is present until 100% correct where then the trend levels off. The more practice the student has, the better expected to perform on the exam.

Below 100% correct for end-of-chapter challenge activities, Exam 2 resulted in the largest slope and largest Pearson coefficient, while Exam 1 had the lowest Pearson coefficient and Exam 3 had the lowest slope. High exam scores were recorded for <5 students who did not complete most, or all assigned questions. These students are considered outliers in terms of end-of-chapter problem completion. Greater than or equal to 100% resulted in decreasing slopes and Pearson coefficients as exams progressed. Exam 3 resulted in a slightly negative slope, which may be due to an outlier who correctly completed 277% of assigned challenge activities but scored 70% on the exam. A low Pearson coefficient signifies a poor linear correlation, which for students completing more than required is shown to have flat trend lines. Those who overachieve on challenge activities are more likely to receive higher exam grades which corresponds to an A or B. The y-intercepts for greater than 100% for all exams is in the B range and since the trend lines

closely represent horizontal fits, students who overachieve, correlate to high exam scores. Those who overachieve on challenge activities are more likely to receive higher exam grades, which corresponds to an A or B. The y-intercepts for greater than 100% of required for all exams is in the B range. Since the trend lines closely represent horizontal fits, students who overachieve, correlate with high exam scores.

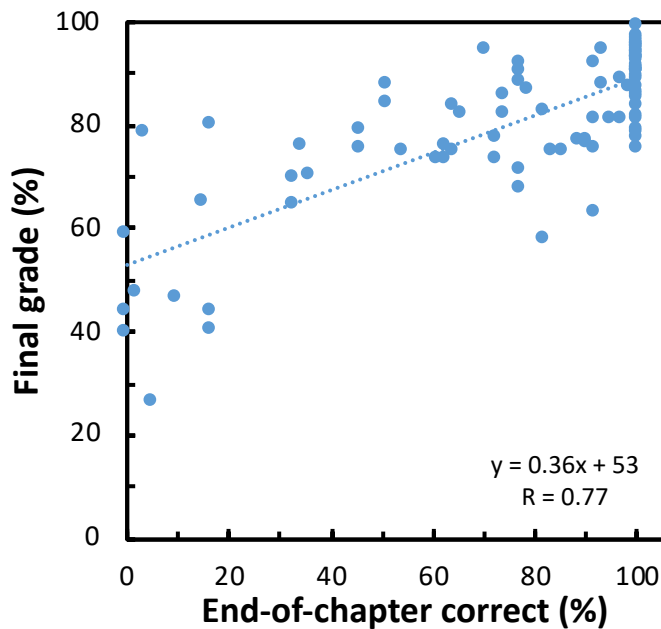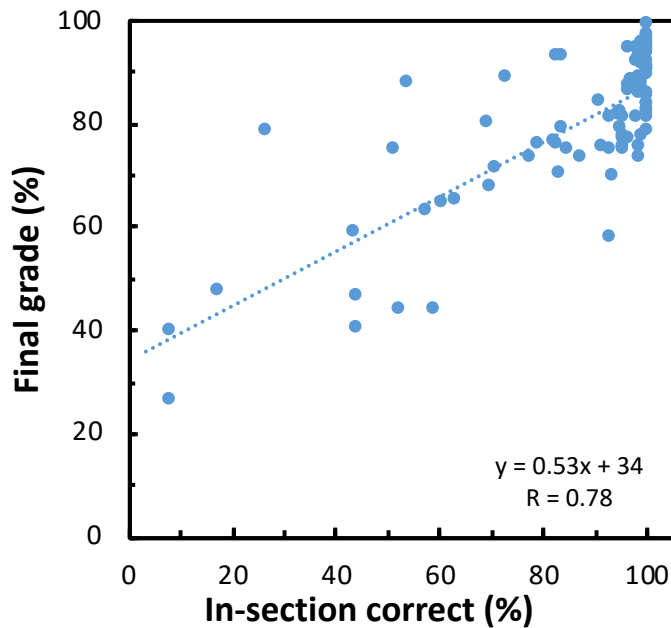Does correctly completing more problems make a difference?

Figure 4. Top. Final grade as a function of fraction correct of in-section challenge activities. Bottom. Fraction correct of end-of-chapter challenge activities.

When comparing final course grades to fraction correct of both in-section and end-of-chapter challenge activities, similar, positive correlations were found (Figure 1). In-section correct was aggregated from fraction correct of challenge activities assigned across Chapters 1 through 7. The maximum score is 100%. End-of-chapter correct was aggregated from fraction correct of challenge activities assigned before each exam, but here, is capped at 100% for a direct comparison with in-section correct. Thus, completing over 100% of the end-of-chapter challenge activities, as presented earlier, is re-adjusted to 100% in Figure 4Figure 1. Final grade as a function of in-section correct resulted in a positive linear correlation with slope of 0.53 and Pearson coefficient of 0.78. Furthermore, final grade as a function of end-of-chapter correct resulted in a positive linear correlation with slope of 0.36 and Pearson coefficient of 0.77. In-section correct data qualitatively shows less variability than end-of-chapter correct. Specifically, four students fall below 20% in section correct, while 15 students fall below 40% end-of-chapter correct. For both formative (in-section) and summative (end-of-chapter) challenge activities, the more correctly solved challenge activities correlated with higher final grades.

Conclusion

Student usage and course success related to auto-graded, end-of-chapter problems was explored. Providing students with summative practice problems before each midterm exam included a requirement of completing only a percentage of the available problems to receive a full homework grade. Many students correctly solved auto-graded problems that did not directly improve their grades. High engagement and preparation were confirmed by students scoring above the median exam score with median fraction correct on end-of-chapter challenge activities at least 100% for all three exams. Exam 1 showed the highest fraction correct and largest percentage of students correctly completing more than required, which may be related to having in-person instruction or some content that was covered in previous courses.

Correctly completing more end-of-chapter problems positively correlated with all three midterm exam grades, which were quantified by high Pearson coefficients. The positive linear correlation was larger for students completing less than 100% of the required problems. Since previous research found that success on homework problems increases with letter grade, when comparing final course grades to fraction correct of both in-section and end-of-chapter challenge activities, strong positive linear correlations were present. Since problem solving skills exhibited on auto-graded problems transferred to new problems on exams, these findings add to the literature related to focused practice.

Acknowledgments

Disclaimer

One of the authors may receive royalties from sales of the zyBook detailed in this paper.

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