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Reading Anytime: Do Students Complete Missed Readings After the Due Date When Using an Interactive Textbook for Material and Energy Balances?

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Abstract

Big data is driving decision making in many industries, and similar, quantitative assessments can be applied to engineering education when appropriate tools are deployed. In this study, a fully interactive online textbook, Material and Energy Balances zyBook, has been used to quantify reading and homework scores. In total, three cohorts of data representing over 280 students and almost 300,000 reading interactions are aggregated in this work. Recently presented results found median reading rates as high as 99% for over 1,300 interactions per student. However, all previously reported reading data was taken when reading assignments were due throughout the semester. New reading data taken at the conclusion of the semester found that many students completed reading without the incentive of earning a course grade. Both 1st quartile (capturing 75% of the class) reading rates and the fraction of the class completing 100% of the reading participation increased significantly after the due date. Additional reading after the due date encompassed 30 to 50 clicks by median and over 400 interactions for some students.

Introduction

Active learning techniques are central to many engineering education discussions, talks, and publications, e.g., [1-6]. With both individual and meta-studies exhibiting benefits of active learning for many learners, the interest appears warranted. Despite the evidence, active learning has not been universally adopted in engineering courses with full-class lectures and static textbooks still common. If a professor doing disciplinary engineering research does not adapt to new research in their field, they are left behind. However, if the same professor adopts the same lecture and textbook for decades, little incentive to modernize the classroom is offered at many, research-focused universities. Here, the focus will be innovation at the cross section of active learning and textbooks.

Textbooks for core, undergraduate courses have enjoyed continuous use while only being updated significantly once per decade or less, e.g., over 40 years eclipsed between the first and second editions of Bird, Stewart, and Lightfoot's Transport Phenomena [7]. High prices, static text, and dated figures do not resonate with many digital natives in today's higher education classrooms. Having grown up with freely available information via web searches and constantly upgraded devices, purchasing and sitting down to read textbooks is not usually a preferred form of study. Some work in recent years is bringing together the textbook and digital world. Interactive textbooks are examples of the convergence of previously static text and the function of ubiquitous digital devices. Interactivity allows students and instructors to monitor progress in real time, usually through the recording of clicks. These clicks can quickly be aggregated to create 'big data' for identifying students' engagement as well as competence and also lead to improving the textbooks' content or delivery. Using interactive textbooks, active learning now reaches course materials as well as in-class activity.

The foundational undergraduate chemical engineering course known as Material and Energy Balances (MEB) is the topic of the interactive textbook discussed here. The course introduces students to concepts central to chemical engineering and problem solving, such as conservation of mass and energy. Course-level details and pedagogical innovations are beyond the scope of this work, but a significant literature can be found (e.g., [8, 9]).

Textbook reading rates for this course have been discussed previously [10-12]. Specifically, high reading rates – median reading rates greater than 90% - have been observed [11], while limited data over recent decades show significantly less reading for traditional textbooks [10, 12, 13]. While reading rates were reproducibly high for two previous cohorts, several other findings are also of note. While interactive textbook reading is an effort-based activity and grade, statistically significantly higher reader rates were observed for students earning A and B grades in the course compared to C, D, and F cohort [10]. In addition, interactivity allows the beneficial learning concept of repetition to be explored. Animations in the interactive textbook commonly had reading rates over 100%, so some students were re-engaging with the interactive textbook [11]. New work presented here will reiterate these points while expanding upon a new research question.

Reading participation reported previously represented the completed clicks before reading assignments were due. Here, the primary research question is do students who did not complete the reading assignments by the due date return and complete the reading participation. In other words, without the incentive of improving their course grades, will students complete missed reading interactions. Starting with a summary of the features of the interactive textbook, reading participation at the end of the semester will be quantified and compared to reading completed by the due date. New conclusions expand the understanding of active learning's interface with textbooks.

Materials: A fully interactive textbook

The interactive textbook of interest is published by ZyBooks, whose motto is less text, more action™. ZyBooks' course materials are interacted with in any HTML5 compliant web browser without additional plug-ins. The Material and Energy Balances zyBook contains a number of features common to paper textbooks (Table 1), and the digital format allows for updates several times per year. One author of this paper is also the lead author of the MEB zyBook. Current subscriptions are $58 per student per semester; Re-subscription costs <$20 per year. Greater than 1,000 interactions are documented throughout the book. Specifically, trends in reading participation, which monitors completion not competence, allow the research question to be answered.

Table 1. Features of the MEB zyBook as of February 2019.

Feature	Number
Sections with content	82
Animations	140+
Clicks to read whole book	1300+
Homework/example questions	200+
Auto-graded challenge problems	400+

Reading participation data from the Material and Energy Balances zyBook were generated at public research university during Spring semesters of 2016, 2017, and 2018, which expands upon previous publications [10-12]. The course consisted primarily of freshman students with enrollment between 88 and 105 students, approximately 60-65% male and 35-40% female. The same instructor led the course for all three cohorts, and the expectations for reading participation were very similar. Specifically, 5 or 6% of the final course grade was earned by students in each cohort.

Sections and subsections of the MEB zyBook are divided into chunks for learners to read and interact with, which is consistent with cognitive load theory. Cognitive load theory centers on working memory, which has a limited capacity when learning new concepts [3, 14-16]. Also, engaging both vision and touch within the digital platform, cognitive load theory postulates partially independent subcomponents of working memory related to the senses. Other cognitive and learning theories have been discussed in previous publications [10, 12].

The style of each section of the MEB zyBooks progresses from definition to demonstration to practice to challenge. Definitions are fully indexed like most electronic books. Animations use 3 to 6 steps to demonstrate previously defined concepts (Figure 1); Animations combine text and images, which has learning benefits [14]. Types of animations include derivations, figures, and actions occurring in process units. Taking 30 seconds to 2 minutes to watch, animations align with humans' attention span inferred from billions of video watches [17]. Practice involves no risk reading participation using multiple choice, true and false, or matching exercises (Figure 2). Each click provides instantaneous and unique feedback, or where less text becomes more text. Challenge activities are auto-graded online homework with rolling numbers and content. Learning questions and challenge activities are scaffolded [6]; Success on easier questions being followed by more difficult questions will be addressed in a future publication.

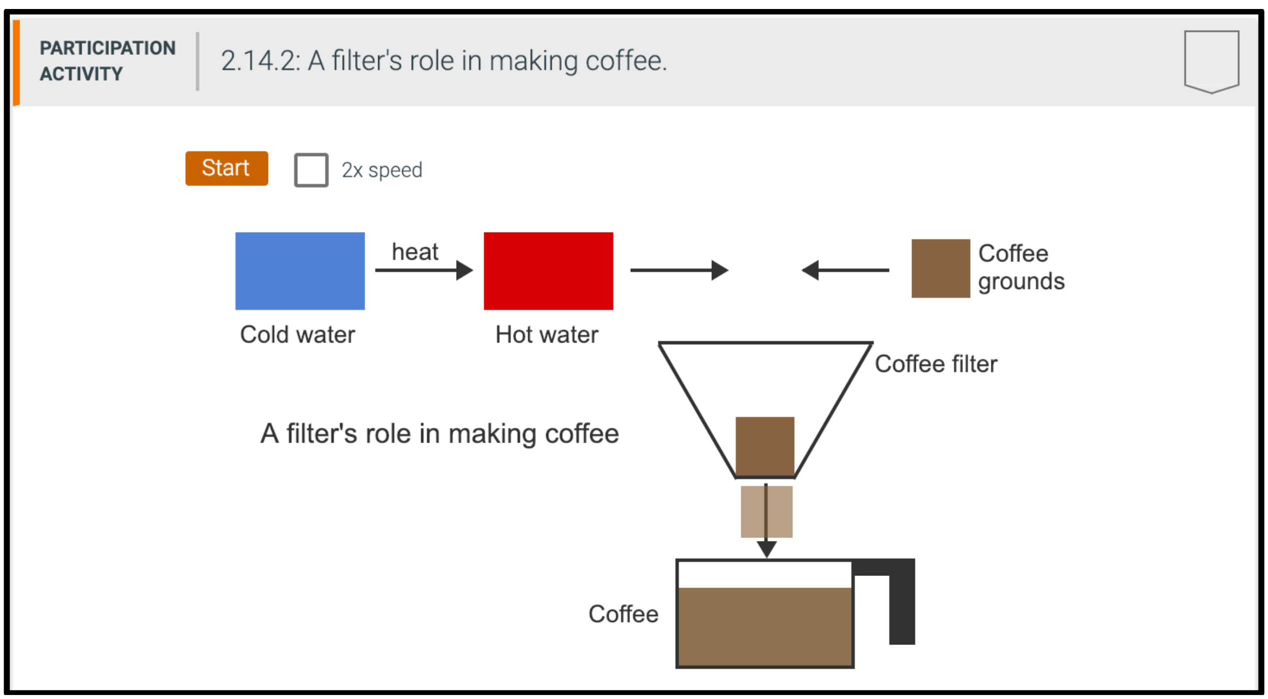

Figure 1. Starting screen of an animation in the MEB zyBook, which is built over several steps.

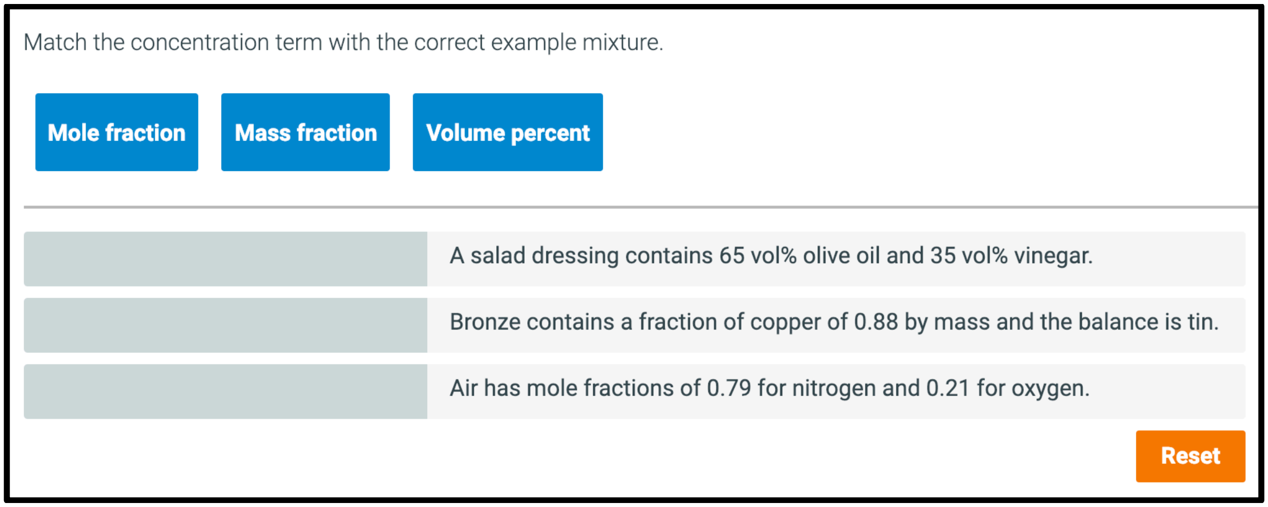

Figure 2. Example of matching style question set before completion.

Results and discussion

Reading participation from the interactive textbook has been reported previously and will be summarized here to help address the current research question. Reading assignments were due approximately every week, and only reading participation completed before the due date were presented previously. Students, professor, and teaching assistants can monitor reading and challenge activity progress in real time. Instructors can also examine specific past time points, e.g., 9am on Monday last week when an assignment was due. Clicking without reading was studied by other researchers, who found about 1% of students tried to game the reading participation process [18]. Using student-reported data from end of semester surveys, reading assignments take 1 to 2 hours per week for about half of the class.

For the current research, reading participation at the due date may be consider the base rates [19]. Students earn about 5% of their total course grade for completing reading before the due date, and no credit for reading after the due date. Similar, nominal incentives have led to high reading participation in other studies [20]. Over 280,000 clicks for reading participation were recorded across the three cohorts. Compared to significantly lower reading rates reported over several decades [21-25], fully interactive textbooks demonstrate high levels of student engagement.

While combining mean and standard deviation encompasses the majority of data within a data set following a normal distribution, other metrics can provide a broader picture when examining data from a cohort of students. Quartiles divide a cohort into four equal subsets; 1st quartile, median, and 3rd quartiles quantify reading participation for three quarters, half, and one quarter of a cohort, respectively. Here, 3rd quartile reading rates are almost always 100%, so the data will not be presented or discussed further; the top quarter of students in a cohort are responsible and astute students making this finding unsurprising. Median reading rates (blue bars in Figure 3) were measured as 94, 97, and 100% for the three cohorts. Finally, reading rates were as high as 91% in 2018 when accounting for 75% of the students (or 1st quartile). Therefore, at least 75% of the class in 2018 (n=98 students) completed at least 1,200 interactions within the interactive textbook before the due date.

With high reading rates potentially being influenced by earning a grade, would students complete missed readings when no direct change to their course grade occurred. In brief, many students do complete missed reading after the due date (Figure 3). Median reading rates improve to 100% for all three cohorts, and 1st quartile reading rates improve significantly to between 98 and 100% across the three cohorts. These new findings confirm students' engagement with the interactive textbook independent of earning a grade.

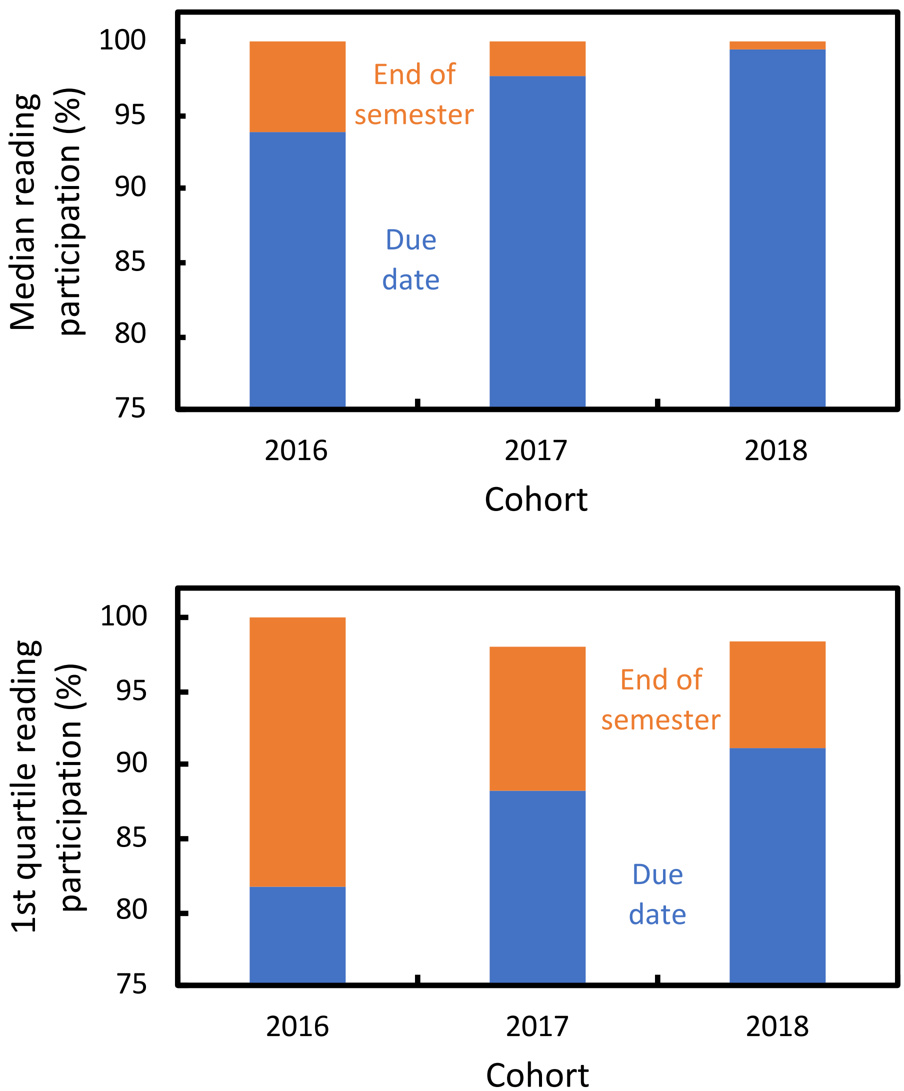

Figure 3. Median (Top) and 1st quartile (Bottom) reading participation for three cohorts at the due date as well as the end of the semester.

Measuring the fraction of students who completely read every section of the interactive textbook further distinguishes reading completed by the due date or at a later time during the semester (Figure 4). Between 53 and 83% of the class completed 100% of the reading participation across three cohorts. The fraction of the class completing missed reading participation after the due date varied from 20 to 73% (orange bars in Figure 4). The largest gain after the due date was for the

2016 cohort. Possible explanations include the interactive format was completely new, the number of clicks were smaller than later years, and 2016 version of the book did not contain auto-graded homework problems. The addition of auto-graded problems with rolling numeric values provided a more robust way to study and check your work than completing the same matching or multiple-choice question set. An analogy may be drawn to gamification [26], seeing a 100% reading score within their own book is like completing all of the levels in an app or video game.

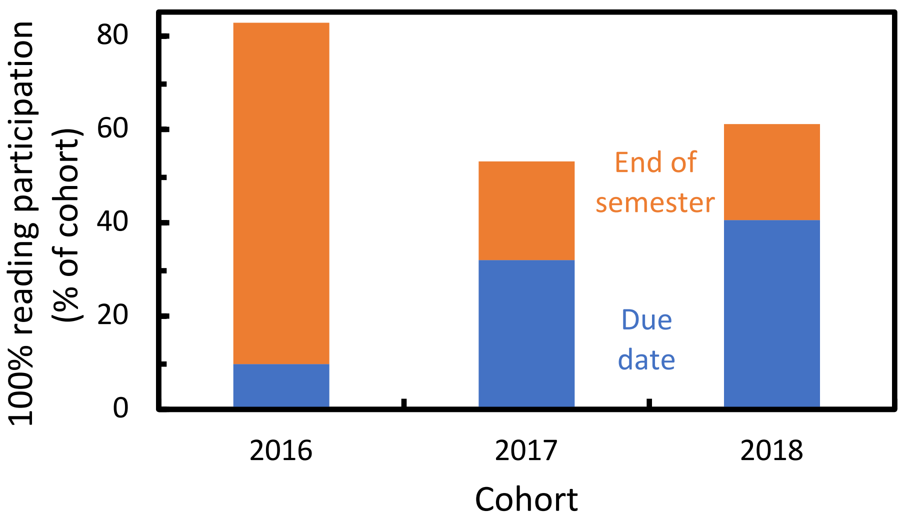

Figure 4. Fraction of class earning 100% reading participation at the due date and end of semester for three cohorts.

Finally, quantifying how much effort after the due date using the number of clicks provides another perspective (Figure 5). For 180 students across the three cohorts, additional reading translated to 32 to 56 median clicks after the due date. At least one student in every cohort completed over 400 additional clicks after the due date. Since reading participation before the due date correlates with final course grades [10, 12], hundreds of additional clicks after the due date may not be sufficient to earn higher grades in the course. Therefore, significant reading participation after the due date is probably not a good study technique, e.g., spaced repetition [11, 27].

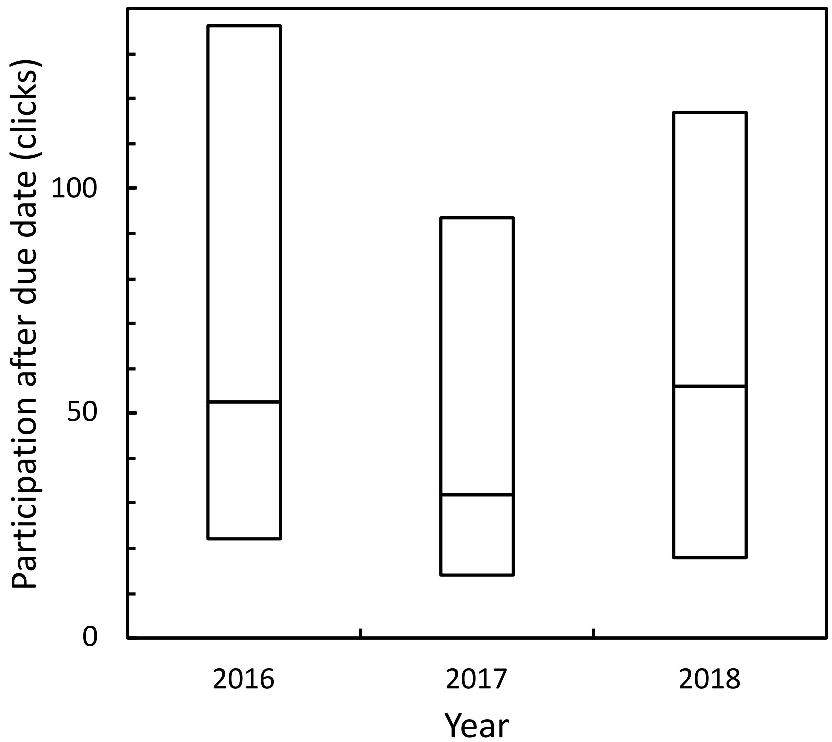

Figure 5. Box plot showing 3rd quartile (top), median (middle), and 1st quartiles (bottom) participation after the due date - quantified by additional clicks – for three cohorts (n = 83, 53, 38 students for the 2016, 2017, and 2018 cohorts, respectively).

Conclusion

Overall, interactivity leads to large data sets on students' participation and effort, which should be independent on course content. Here, a fully interactive online textbook - Material and Energy Balances zyBook – provided big data by measuring reading participation and homework success. Three cohorts composed of over 280 students generated almost 300,000 reading interactions. Previous work found median reading rates as high as 99% for reading completed by weekly due dates. Now, reading participation from the end of the semester found that many students completed additional reading. Despite not earning points toward their course grade, median and 1st quartile reading rates as well as the fraction of the class completing 100% of the reading participation increased significantly after the due date. From 30 to 50 clicks by median and over 400 interactions for some students, reading after the due date is common.

Since previous work has shown a correlation between reading participation before the due date and final course grades, reading after the due date may be considering cramming. Since cramming is not a learning best practice [28], reading after the due date likely does not allow sufficient time to form new connections in the brain that could help on exams that make up most of the final course grade. Answering the current research question spawns several new, and possibly more interesting, questions for future study. For example, could quantifying when the reading after the due date test the inference about cramming not leading to higher grades.

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Disclaimer

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

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