Evaluation of an Interactive Top Hat Text for Engaged Learning

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***Abstract*—This Innovative Practice Full Paper notes that recent research has indicated that large numbers of college and university students make limited use of their class textbooks. This is particularly true in terms of assigned readings – whether they are required for the course or not. Students are knowingly depriving themselves of an important means of learning. While the falling use of textbooks among students is concerning, it should be especially so because of the ongoing pandemic. The pandemic has forced much of the secondary educational experience online, limiting forms of in-person lectures and group activities, and severely restricting or rendering impossible hands-on assignments such as labs and projects. It is clear that the current environment students find themselves in is not optimized for learning.**

In an attempt to increase student understanding of course material, an online, interactive textbook was created using the software platform Top Hat. The book is in its first edition, and is for use with the university's engineering course Statics and Mechanics of Materials. It was written and developed by a professor with years of teaching experience and course development, and by a student who had previously taken the course and has worked as a certified tutor for the university. The textbook employs pedagogies designed to increase student understanding of material, such as active learning, and is used in conjunction with a flipped classroom format. To facilitate this approach, the book has readings that are to be completed before lecture in preparation for various class activities, including group assignments and discussions and think-pair-share. Questions are embedded within the assigned readings for the students to check their understanding of the material. These questions provide instant feedback to the students, either informing them their answer was correct, or alerting them it was incorrect and giving hints to help solve the problem.

As the textbook makes use of educational strategies known to improve student learning, it is desired to know if the book had a positive impact on their understanding of the course material. One method of evaluating the online text is to compare students' text use with their level of achievement in the course. Two factors related directly to text use were investigated: the number of questions in the textbook students answered correctly (Correctness) and the number of questions in the textbook answered in general (Participation). The students were categorized into three levels (low, medium, and high) based on their respective score for each variable and two, one-way between-subjects analysis of variance (ANOVA) were performed to determine if there existed a significant difference between student textbook usage (participation and correctness) and overall course grades. Post hoc testing was then performed to determine differences between the three groups. Both F-tests were significant, with significant differences found between the different groups for both correctness and participation. The largest difference occurred between the top and bottom thirds of the class with respect to question correctness, with the difference in mean final course grades being a full letter grade.

***Index Terms*—On-line textbook, interactive textbook, student engagement**

I. Introduction

While textbooks are required for most collegiate courses, there is a marked lack of student engagement with their text, as well as an implicit misunderstanding of how the text should be used to supplement student learning. Results from the 2017-2018 National Survey of Student Engagement (NSSE) survey provide some insight into student textbook usage [1]. When looking at all Carnegie 2015 Basic Classifications for U.S. institutions only, three questions are directly related to textbook usage. The first question (denoted Q1) comes from the Engagement Activities section, and asked students the frequency they "come to class without completing readings or assignments." The second question (denoted Q2) comes from the Course Engagement section, and asked students the frequency they "identified key information from reading assignments." The third question (denoted Q3) comes from the Time Spent on Various Activities section, and asked students "of the time you spend preparing for class in a typical 7-day week, about how much is on assigned reading?" The results of this survey, administered to first year and senior students groups, with corresponding respondent population (denoted Pop.), is summarized in Table I.

In regards to Q1, it is seen that 74% of first year and 75% of senior student very often, often, or sometimes never consult their text when reading is assigned. Only a quarter of respondents indicated they always completed the assigned reading prior to coming to class. When considering the responses to Q2, a higher percentage of respondents - 28% for first year students and 35% for seniors, indicated they were able to either locate or recognize key course content within their text. About half of both groups indicated they often identified important information from their text, but that does not necessarily indicate their level of engagement with the text in pursuit of necessary information. Once again, about a quarter of respondents from both groups indicated they sometimes or never found essential material within their text.

TABLE I
SUMMARIZED RESULTS FROM 2017-2018 NSSE SURVEY

		Response Category			
Item	***Year (Pop.)***	***Very often***	***Often***	***Sometimes***	***Never***
Q1	First year (n=245,080)	5%	13%	56%	26%
	Senior (n=302,179)	6%	15%	54%	25%
Q2	First year (n=204,131)	28%	49%	21%	2%
	Senior (n=262,872)	35%	44%	19%	2%

		Response Category				
Item	***Year (Pop.)***	***Almost all***	***Most***	***About half***	***Some***	***Very little***
Q3	First year (n=192,235)	7%	20%	29%	33%	11%
	Senior (n=251,176)	10%	22%	29%	28%	14%

Lastly, when asked about how much of their class preparation was spent on assigned reading (i.e. Q3), 56% of first year students and 61% of senior students indicated they spent about half or more of their time interacting with the textbook. The disconcerting statistic from this question is that 44% of first year students and 42% of seniors indicated some or very little of their time was devoted to reading the textbook.

Additionally, at Oregon State University (which was not included in the 2017-2018 NSSE survey), two hundred undergraduate students were asked to complete a survey measuring student perception of their course's textbook [2]. Over three-fourths of students indicated that one of the motivating factors for purchasing a text was simply because the course required it or their homework came from it, and there were little ways to find the problems otherwise. Less than two thirds of students indicated they would purchase a textbook because they find it an effective learning tool. Additionally, more than three-fourths of the students indicated that the cost of the textbook was a deterrent and when a course required the text, they looked for the cheapest option.

To mitigate publishing cost, and consequentially the cost to students, textbooks have recently made a shift to digital formatting (i.e. a PDF copy of the physical text) [3]. A research group lead by Chen, investigated student attitude towards the efficacy and implementation of an online textbook for three different engineering courses: Mechanical Controls, Manufacturing Organizations, and Introduction to Thermodynamics [4]. The text was a digital version of the printed text traditionally used for the course. A survey comprised of a combination of multiple choice and open response questions was presented to the students of each course. While some students in every course enjoyed the textbook due to its low cost and convenience, a vast majority of students were dissatisfied with the online text. Key complaints among students were technical difficulties, the lack of worked out examples within the text, the information being difficult to read off a screen, and that the online text was just not an effective learning tool. Researchers did note that student attitude towards the online text in Manufacturing Organizations was more positive overall than the other two courses. It is speculated that this positive attitude students had toward the text was due to the many complementing assignments the course implemented that were based on online research and case studies. From the limited literature it can be seen that merely transitioning the text to a digital format is not enough to increase student engagement although it decreases costs to students. To further student engagement with the text, efforts have been made to not only make the text in a digital format, but to restructure the text to have interactive components.

Liberatore studied the effect of interactive textbook usage on student performance and student outcomes in an introductory chemical engineering course [5]. The study was motivated by prior NSSE studies which indicated a non-negligible percent of students do not utilize the assigned texts to complete reading assignments. To such an end, the author of the study created and implemented an interactive digital textbook, a ZyBook, and evaluated its use in comparison to a traditional book, and how its usage correlates to student performance and feelings of engagement. Liberatore found that lesser-performing students (those who earn C, D and F grades) complete less assigned reading, and with statistical significance, than those students who earn A and B grades. The cut-off threshold for this comparison was 90% completion. Those students who earned A and B grades, 82% of them on average completed 90% or more of the assigned reading (as tracked by participation). Of the students that earned C, D and F grades, only 36% completed 90% or more of the assigned reading. Furthermore, surveys conducted during the usage of the book indicated 46% of students found the book to be interactive, 39% found the book to be concise, while 20% of the students enjoyed the animations, found the text easy to understand, and thought it was well organized. Lastly, 16% of the respondents positively viewed the feedback the text provided when an answer was responded to incorrectly. Ultimately, 87% of the respondents felt the interactive, online text to be useful in the course, which was a marked increase from 66% and 73% of students that felt prior iterations of a similar online text was useful.

As evidenced by such high percentages of students reluctant to use their course's text from literature, it is wondered what could motivate them to engage more with their text. With over one thousand student participants, French was able to evaluate the how many students frequently use their course's required textbook, what motivates them to read and engage with the text, and what aspect of the course they depend on most to learn the material [6]. In classes where the textbook was required, 59% of students reported their main form of learning the material was through lecture while only 35% relied on the textbook to learn. Conversely, in classes where the text was not required, 40% of students relied on lectures for learning and 36% on the textbook. In both groups, the remaining percentage of students reported either assignments, labs, practicals or tutorials, discussion with other students, or other sources on the internet as their main form of learning. It was also found

that in courses where the textbook was required, 59% of students reported reading the text often, 20% sometimes, and 19% rarely. For non-required text courses, 50% read often, 27% read sometimes, and 22% read rarely. In courses where portions of the students' grade came from reading the text (e.g. reading quizzes or graded in-class discussions), textbook usage was seen to be higher with course grade being a motivating factor. The researchers also made note that there was not a significant correlation between reported textbook use and overall course grade. This conclusion is contrary to that of Liberatore.

While multiple studies have been conducted on the usage and efficacy of required textbooks for college courses, there are many factors to consider when evaluating a student's relationship with their textbook: does the text work well with the course format, how expensive is the book for students to access, is the student actively using the text (i.e. active versus passive study), and is there an incentive for students to be continuously using the text? To this end, the authors wrote an interactive textbook on Top Hat's online learning platform for an introductory engineering course, Statics and Mechanics of Materials [7]. To ascertain the effectiveness of the interactive, online textbook, and its effect on student performance, two, one-way between-subjects analysis of variance were performed on overall course grades as a function of first question correctness, then question completion among each of the three student groupings.

II. Methodology

A. Development and Implementation of On-line Textbook

Details of the construction of the text, as well as results of surveys on student perceptions about the use of the text, can be found within [8]. However, a brief summary is provided herein. The text was built in a concept-example-question pattern as to minimize cognitive load [9]. The use of this textbook was coupled to other pedagogical techniques, including a flipped classroom via the use of pre-recorded lecture videos and synchronous instructor-led in-class examples, and think-pair-share and group activities using Top Hat worksheets, one of the many features within the Top Hat platform that promotes active learning in the classroom [10]. Homework and quizzes were also administered through the online textbook, while synchronous instructor-led examples were broadcast live to student devices via Top Hat's presentation mode. Additionally, the text incorporated project based learning, where content required for the project was incrementally introduced and accessible to students during the administration of the project. This cohesive platform provides a more structured and interactive approach to course instruction, administration, and evaluation.

Students engaged with the text through two modes of administration. The first mode was through assigned readings. Students were assigned sections of the text to read prior to class. Within the readings, students were presented with embedded questions typically following in the introduction of a concept or after an in-depth example. The embedded questions came in a myriad of forms (e.g. multiple choice, word answer, numeric answer, fill in the blank, matching, click on target, sorting, long answer), and were based upon the immediately preceding material. These embedded questions would provide immediate feedback about correctness of the student supplied answers, and some would provide hints when an incorrect answer was entered. These questions recorded both participation and correctness. There were 195 of these questions embedded throughout the text.

The second mode of administration came through in-class Top Hat worksheets. After the instructor-led in-class examples, students broke out into teams, which were constructed via CATME [11], and worked through a series of lecture-specific embedded questions. The instructor and teaching assistants were available to help teams during this period of lecture. Students had one week from the conclusion of a lecture to complete the worksheet. In totality, there were 159 questions administered through the in-class worksheets. Once again, participation and correctness were recorded. To incentivize students to complete both the assigned reading and in-class worksheets, participation constituted 10% of the students' course grade. The percent for which participation comprised the students' final grade is aligned with a weight compulsory for student engagement [12].

B. Data Analysis

It was desired to know if the use of the Top Hat interactive textbook appeared to have any affect on students' final course grades. To study this, students from both sections ($n = 107$) were categorized into different groups depending on the variable being analyzed. The two variables investigated were the percentage of textbook questions students were able to answer correctly (Correctness) and the total amount of textbook questions they answered (Participation). For each variable, the students were divided into three different groups by their respective percentile, allowing for a nearly balanced design, yielding groups of 36, 36, and 35 students, respectively. In terms of correctness, the top 33% of the class was correct 78-94% of the time, the middle 33% was correct 71-78% of the time, and the bottom 33% had a correctness rate of 70% and less. In terms of participation, the top 33% of the class answered 98-100% of all textbook questions, the middle 33% answered 93-98%, and the bottom 33% answered less than 93% of all questions. In addition, as the final course grades were originally dependent on Participation, this effect was removed before continuing with the analysis.

The results were analyzed with two, one-way between-subjects analysis of variance - one for each variable. The assumptions to accurately use one-way BS ANOVA were checked. An omnibus F-test was then performed, examining the data for differences in students' final course grades among the three groups based on question correctness and the three groups based on the number of questions completed. The results of both F-tests were found to be significant at a level of 0.05. Post hoc comparisons were then performed to determine the differences.

III. Results and Discussion

A one-way between-subject analysis of variance was performed on student's final course grades as a function of the level of textbook question correctness. All assumptions were met with the exception of homogeneity of variance, Brown-Forsythe $F(2, 104) = 5.998, p = 0.003$. As a result, Welch's F-test was conducted instead. There was a significant difference in students' final course grades among the groups based on the number of correctly answered questions, $F(2, 65.62) = 16.507, p < 0.001, \eta^2 = 0.26$.

To investigate where the differences exist among the three groups, Games-Howell was used for post hoc pairwise comparisons. All comparisons showed significant differences on students' final course grades based on grouping. The top 33% of students had better course grades than those of both the middle 33% ($p = 0.012$) and the bottom third of the class ($p < 0.001$). Students in the middle third of the class in terms of correctness also had better course grades than those in the bottom third of the class ($p = 0.005$). The number of participants, mean, and standard deviation for each group are summarized in Table II.

TABLE II
Mean and Standard Deviation of students' final course grades based on number of questions answered correctly

Correctness Group	*n*	*Mean*	*Standard Deviation*
Top Third	36	88.58	5.27
Middle Third	36	84.51	6.43
Bottom Third	35	78.06	9.78

In addition to being statistically significant, it can be seen that a sizeable difference exists between the average final course grades between the three groups. The top third of the class in terms of questions answered correctly outperformed the middle third by nearly half a letter grade, and outperformed the bottom third by an entire letter grade, moving from a C or C+ to a B or B+ for the course. The difference in means between the middle and bottom third of students was also considerable, with the average being over 6% higher for those in the middle group. While not the only factor affecting course grades, students that were able to answer the textbook questions correctly performed better in the course overall.

A second one-way between-subjects analysis of variance was performed on students' final course grades as a function of the level of textbook questions answered. All assumptions are met with the exception of two: outliers and homogeneity of variance. A single outlier exists in the first group, the top third of the class in terms of the number of questions answered. As the group sizes are fairly large, removal of the data point, as well as moving it to the middle third group had minimal effect on the results. As a result, it was kept in the first group. With the violation homogeneity of variance, Brown-Forsythe $F(2, 104) = 4.361, p = 0.015$, Welch's F-test was once again conducted instead. There was a significant difference in students' final course grades based on the number of questions answered, $F(2, 66.71) = 8.011, p = 0.001, \eta^2 = 0.162$.

To investigate where the differences exist among the three groups, Games-Howell was once again used for post hoc pairwise comparisons. The final course grades for students' in the top third of the class in participation and the middle third were not significantly different ($p = 0.208$). The other two comparisons were found to be significant. The top third of the class had better final course grades than the bottom third ($p < 0.001$) and the middle third had better final course grades than the bottom third of the class ($p = 0.020$). The number of participants, mean, and standard deviation for each group are summarized in Table III.

TABLE III
Mean and Standard Deviation of students' final course grades based on number of questions answered

Participation Group	*n*	*Mean*	*Standard Deviation*
Top Third	36	87.32	6.54
Middle Third	36	84.73	6.29
Bottom Third	35	79.12	10.20

While not as sizeable as the differences in means for correctness, it can still be seen that large differences exist for means based on the number of questions answered - whether they were correct or not. The difference between the top and middle thirds of students was not significant, however, there was over an 8% difference in average course grade between the top and bottom third of students based on participation. The middle third also outperformed the bottom third of students by a significant margin, averaging approximately half a letter grade better than their peers in the course. It appears as the number of correctly answered questions does, that being actively engaged with the questions in the textbook is associated with better performance in the course.

It is interesting to note how the standard deviations for the groups in both correctness and participation follow a similar pattern. As the rates of answering questions correctly and of just answering textbook questions at all decreased, students' final course grades began spreading out. While few in number, there were some students that were able to do well in the course with minimal interaction with the text. In addition, some students completed the majority of the questions, but got the majority of them incorrect and still received high marks for the course, and vice-versa. To better visualize the variance among groups with respect to correctness and participation, boxplots for each variable were created and are shown in Fig. 1 and Fig. 2.

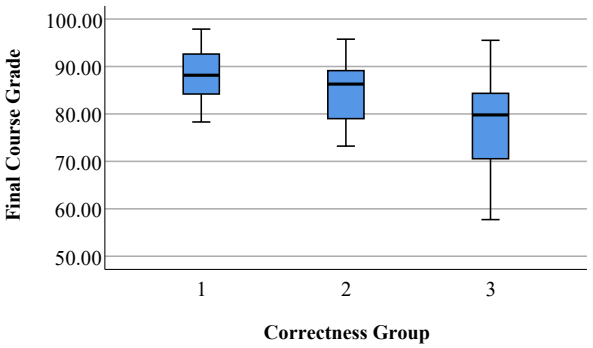

Fig.1. Boxplot of final course grade as a function of question correctness.

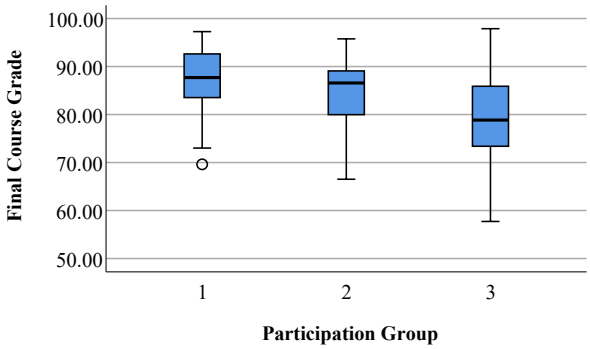

Fig.2. Boxplot of final course grade as a function of questions answered.

IV. Conclusion

To improve student usage of course textbooks, an interactive textbook using the Top Hat platform was created for the introductory engineering class Statics and Mechanics of Materials. The online text, written by the professor and a former student, easily integrated into the course's flipped format and mitigated common quarrels students have with traditional textbook such as cost and ease of access. Students were encouraged to engage with their text through pre-lecture reading assignments that employed active learning through embedded questions throughout the reading.

Many previous studies that have evaluated student engagement with a course's assigned text have relied on student submitted answers and trusted students to be honest with the surveyor and themselves about how often and how well they use their textbook. In this study, there was no need to rely on student input. The researchers were able to track, through Top Hat's grading software, not only a student's participation with the reading assignments but their performance as well. This allows the research team to take account of each student's baseline interaction with the assignment through their participation score and how well they are engaging with their text through their correctness score. This data can then be coupled with the student's course grade to see if a certain level of active engagement with their text correlated with a significant, positive impact.

This study utilized two, one-way ANOVAs to evaluate the statistical significance student engagement with their textbook had on overall course performance. The students of the course were split up into three groups correlating to their amount of embedded questions answered correctly (i.e. top 33 % of the class, middle 33 %, and bottom 33 %). When evaluating question correctness versus course grade, it was found that those in the top third of the class performed, on average, nearly half a letter grade better than the middle third and one whole letter grade better than the bottom third. In the evaluation between question participation and course grade (where groups were reformed into thirds based on the amount of questions answered) the difference between the groups was not as sizable. The top third and middle third did still outperform the bottom third by 8 % and 6 %, respectively.

In future studies, the researchers would like to create an experimental design such that a two-way ANCOVA can be performed to find an interaction effect between student participation and correctness on overall course grade. The research team would also like to introduce student grade point average as a covariate. In addition to researching the effects of active textbook engagement on overall course grade, it would be interesting to see if it appears to affect individual assignments such as the midterms and final for the course. Finally, the researchers would also like to perform the study with different cohorts such that one class section would use the online textbook and another would use the traditional text for the course.

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