2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #38121

A Comparative Study on Student Performance using Traditional and Interactive Textbooks

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A Comparative Study on Student Performance using Traditional and Interactive Textbooks

Abstract

The use of digital learning materials has garnered attention in recent years in an attempt to increase higher-education student engagement with course materials. These materials include, but are not limited to, online lecture videos, online homework assignments, and digital textbooks. Of the latter, some textbooks have merely been converted into a portable document format (i.e., a static textbook), while others have been developed using various pedagogies and educational theories to increase student learning and satisfaction through the incorporation of various interactive features (i.e., an interactive textbook). Although the intent of these different online textbooks is to augment student learning, their efficacy has not thoroughly been scrutinized. To this end, a comparative study between the use of a traditional static textbook and an interactive, online textbook on student performance is presented.

The authors of this study previously developed an interactive online textbook titled "Statics and Mechanics of Materials: An Example-based Approach" using Top Hat's teaching and learning platform [1]. The organization of the textbook followed Cognitive Load Theory (CLT) [2]. Using a concept-example-question format throughout the textbook, learning was compartmentalized. Students were presented with theoretical constructs and governing equations, followed by an in-depth, illustrative example. Immediately following the illustrative example, students would be presented with embedded questions. Embedded questions are interactive questions that exist within the body of the textbook. There was a myriad of embedded question types: multiple choice, word answer, numeric answer, fill-in-the-blank, matching, click-on-target, sorting, and long-answer. Regardless of the question type, students would answer multiple embedded questions related to the preceding material where both their basic understanding of the underlying concepts and ability to work through the presented problem-solving methodology were evaluated. By answering the embedded questions, students would receive immediate feedback on their understanding and problem-solving abilities. Previous studies concerning this interactive, online Top Hat textbook have indicated that students found the online textbook more engaging than a traditional textbook [3], and showed a positive correlation between engagement with the textbook and final course grade [4].

The current study consisted of two groups of undergraduate students enrolled in a Statics and Mechanics of Materials course. This course is administered to sophomore, junior and senior students from a variety of different engineering majors. One group (n = 73) used the curriculum-specific Top Hat textbook, while the other group (n = 109) used a traditional textbook, which was an abridged version of "Statics and Mechanics of Materials: An Integrated Approach" by W. Riley, L. Sturges and D. Morris [5], and "Mechanics of Materials" by W. Riley, L. Sturges and D. Morris [6]. Student performance was quantified through graded assessments, namely midterms and a final exam, and as well as their overall course grade. The effect of the assigned

textbook on student performance was then compared using t-tests. Student perceptions of their respective textbooks were also collected through surveys and analyzed using qualitative methods. There was no statistically significant difference in student performance considering the use of the Top Hat textbook in comparison to the traditional textbook. However, students felt more engaged with the course and material when using the Top Hat textbook.

Introduction

Statics and Mechanics of Materials I is a foundational class for many sophomore students who have just entered an engineering program at the authors' university. This course is taught to a diverse group of engineering disciplines, including but not limited to mechanical, biological, chemical, industrial, and electrical engineering students, as well as engineering science majors. The knowledge gained herein provides the foundation for many other topics covered later in their academic careers—the retention of this information is crucial to their future success. This course also sets rigorous standards for the students' future studies. With these high expectations, students often struggle due to the fact they are not only learning engineering concepts for the first time, but they are also learning how to learn.

As educators, it is our imperative duty to find instructional methods that best deliver not only requisite information to students, but in a manner that is also conducive to critical thinking. An increasing number of studies suggest that the use of traditional textbooks may not be the most efficient or cost-effective means of education. To the latter point, multiple studies have been conducted on textbook prices for over five decades. Textbook prices have increased 1,000% from the late 1970's to the mid-2010's. Throughout the 1980's, prices were increasing three times that of inflation, and four times that of inflation through the 2000's [7]. From January 2006 to July 2016 the prices of textbooks alone have risen 88% [8]. More recently, from July 2011 to July 2021, the prices of textbooks has increased 36% [9].

To put these percent increases into perspective, collegiate textbook prices currently range from \$68 to \$182 [10]. This translates to students currently spending about \$1,200 to \$1,300 a year on textbooks and supplies, which is about 26% of the total tuition cost at a public four-year university [7]. However, these high prices generally refer to hardcover copies of the textbook. Students can also purchase loose-leaf copies as well as online versions of the textbook for a lesser cost [11]. Some textbooks have the option of renting a digital version as well. Students may also be pirating textbooks online. Nonetheless, this continual increase in textbook cost has resulted in decreased textbook purchases. A survey of 1,067 students in 2016 found 66% of students claiming they did not purchase the required textbook for a given class [12]. Another study from 2020 yielded similar results with 65% of students claiming they did not buy a required textbook for class due to costs [7]. Cost may not be the only issue at fault, as there is still a lack of usage from students who do acquire the required textbook.

Lack of textbook usage is reflected in a 2008 study where undergraduate finance students were surveyed on the utilization of their assigned textbooks [13]. The online survey was sent to students in 10 different course sections at three different universities. The response rate was approximately 32% with 264 usable survey responses. One question was related to the frequency in which students read the textbook for their class. Approximately 20% of the students reported

they did not read the textbook while about 40% said they spend less than one hour per week with their textbook. Another study involving psychology students yielded similar results [14]. These smaller studies are aligned with the results from the 2017-2018 National Survey of Student Engagement, in which 74% of the 245,080 first year and 75% of the 302,179 senior student respondents "very often," "often," or "sometimes never" utilize their textbook for assigned reading assignments [15]. There are many reasons for lack of usage after purchase. One plausible motivating factor in decreased usage is the static nature of many digital textbooks.

Historically, traditional textbooks were the main mode of disseminating written information, but now there are new modes of communication. Students now appear to be open to the idea of a new form of textbook, as well as a new form of delivery. A survey [16] given to sophomore-level chemical and biological engineering students (n = 627) posed the question: "Many types of textbooks are available for engineering courses. Which type of engineering textbook is most appealing to you?" The four options that were presented to them were a "Traditional Paper Textbook," "Electronic Textbook," "Electronic Textbook with Interactive Figures," and "Electronic Textbook with Interactive Example Problems." The majority of students said the "Electronic Textbook with Interactive Example Problems" was the most appealing. The interactive, online Top Hat textbook used in this study falls within the categorical description of last item, "Electronic Textbook with Interactive Example Problems." Looking at other studies [17, 18, 19] which include the use of interactive textbooks, it is seen students like certain aspects of these styles of textbooks. These include features such as questions with feedback, animations, and simulations. These same students also commented that they feel more motivated to learn using an interactive textbook, that the textbook increased their interest in the class, and that the textbook also made the class more efficient.

Another study from 2009 was conducted to see the impact on learning from a web-based interactive statics course [20]. The study consisted of 110 students, and researchers tracked student use of interactive exercises, referred to as tutors, for each module. They then compared the grades of quizzes for each module for those who used low (one to six), medium (seven to 14), and high (15 to 23) numbers of tutors per module. There was a statistically significant increase in performance from the students who had medium- and high-use of the tutors compared to the low-use group. Other similar studies [21, 22] have been conducted and have either shown an improvement in student performance or no change in performance. A study was conducted in 2013 to investigate students' performance compared to the length of text used to cover a topic [23]. The 307 participants of a basic computing class were randomly assigned to one of two groups. One group used a normal text style of six to 12 sentences with one to three examples to cover a topic, while the other group used less text, on the order of one to two sentences and one to three examples. The students would take a pre-lesson quiz, then read their corresponding lesson and take a post-lesson quiz. The results showed the group that used a textbook with minimal text had a larger improvement in their average assessment score than the control group.

In an effort to not only improve student learning through engagement, but to also provide a less expensive educational resource, the research team developed an interactive, online textbook [1]. The textbook was built using CLT and was designed specifically to meet curriculum and programmatic learning objectives, which yielded a brief yet thorough presentation of the required material. Cognitive Load Theory refers to the process of working with the information processing

stages students naturally possess to best ensure presented information is stored in long-term memory [2]. That is to say, CLT guides instructional design to reduce cognitive load in learners. The three types of cognitive loads learners experience are intrinsic, extraneous, and Germane. Intrinsic loads are related to the complexity of the task or subject at hand. Extraneous loads are related to unrelated tasks or subjects that create distractions during the learning process. Germane loads are related to the association of newly gained knowledge with pre-existing knowledge. Since the working memory, sometimes referred to as the short-term memory, is limited and must not be overloaded during learning, CLT is based upon reducing working memory load to promote the conversion of information from short- to long-term memory, i.e., reducing intrinsic and extraneous loads.

The textbook used in this study was organized according to CLT, as described in [3], and elaborated upon in the following. The students were presented with their learning objectives at the beginning of the chapter. Each section within the chapter directly corresponded to one or multiple learning objectives. Once the students were in a section, they were briefly presented with the concepts and requisite mathematics. Superfluous derivations or equations were omitted; only the necessary information for the section was presented, as to not overwhelm the extraneous load. Immediately following this brief introduction, the concepts and mathematics were demonstrated through an in-depth example as to not overwhelm the intrinsic load. After the example, students were then asked to answer embedded questions. These embedded questions increased in complexity, following learning levels of Bloom's Taxonomy [24]. Early embedded questions would test the students' ability to recall information, e.g., define terms. Following embedded questions would then probe students' understanding of the previous concepts by recognizing, identifying, and classifying, e.g., complete matching and/or multiple choice questions to associate terms in equations with physical descriptions, etc. Latter embedded questions would then require students to apply their newly gained knowledge to problems similar to what they saw in the textbook, and then to unfamiliar problems. End of chapter embedded questions were associated with the fourth level of Bloom's Taxonomy, where they would examine, compare, and contrast differences in concepts/methodologies/types of problems. Additionally, these embedded questions provided immediate feedback about the correctness of the student's response, and often would provide hints if they answered incorrectly.

The traditional textbook used in this study [5, 6] also followed CLT. Each chapter was broken down into multiple sections. Each section presented conceptual material which was followed by illustrative example problems, and concluded with both a summary of concepts and applicable homework problems. The homework problems are presented in order of difficulty: introductory, intermediate, and challenge. The authors of the traditional textbook also used an approach called "just-in-time" to organize sections within chapters, as well as the order of chapters [5]. The overall traditional textbook organizational scheme (e.g., sections in a chapter, order of chapters) is inconsequential, for the order in which content was and can be presented to students is and can be the same. Thus, the only difference between two textbooks used in this study is the interactiveness of the Top Hat textbook through the use of embedded questions.

The purpose of this study was to compare the usage of an interactive, online textbook and a traditional textbook on student performance. The research team also wanted to compare the usage of both textbooks and how the students felt about their corresponding textbooks. The interactive,

online textbook was created with a concept-example-question format to maximize exposure to material while both minimizing cognitive load and superfluous material. The added benefit of having a curriculum-specific text is reduced cost. The Top Hat textbook cost students only $40 when the study was conducted, whereas the traditional textbook cost $156 through the university's bookstore during the same evaluation period. The brief yet interactive nature of the Top Hat textbook in comparison to a traditional textbook is hypothesized to improve student performance through increased engagement at a fraction of the cost of a traditional textbook. The scope of this study is currently limited to the authors' university, since it is curriculum specific. However, the findings of this work, in conjunction with findings of prior studies on the development [3] and student use of the textbook [4], can guide other instructors either in the adaptation of this textbook to their courses and/or curriculum, or the creation of their own curriculum-specific textbook.

Methodology

To study the effect of the interactive textbook on student performance, two groups were created out of three sections of a Statics and Mechanics of Material course. A researcher involved in the study was the instructor of record for all three sections. The Top Hat textbook was used within one section (n = 73), whereas the traditional textbook was used within the remaining two sections (n = 109). The student cohorts are denoted as "Top Hat" and "Traditional," reflecting the textbook they used. During the study, t-tests were performed on the two cohorts to search for significant differences between the groups in terms of performance on major assessments. These assessments were chosen because they were uniform for both cohorts. Only homework and quizzes completed by the Top Hat cohort required the use of significant digits, whereas the Traditional cohort did not have to use significant digits in both the calculation and reporting of their answers for their assigned homework and quizzes. These two groups were also involved in a second study involving their course project, therefore the project was removed from the calculation of their final grade prior to the data being analyzed.

For consistency of all other variables, each section was taught in a flipped lecture format with the aid of pre-recorded lecture videos, which were delivered via the university's Learning Management System, Canvas. During class time, in-class instructor-led examples and think-pair-share group activities were administered using Top Hat's platform. To take advantage of Top Hat's presentation mode, all instructor-led examples were electronically disseminated in real time to students' personal devices. Top Hat was also used to provide the students with lecture video questions. The Top Hat platform was chosen as it created a more regimented and interactive classroom experience.

The Top Hat and traditional textbooks were both used by students prior to class. Prior to lecture both cohorts were expected to complete their assigned readings, along with the viewing of lecture videos and answering basic conceptual lecture video questions. The specific sections presented in the videos and readings were further elaborated upon during the instructor-led examples. For the Top Hat cohort, embedded questions were used to signify the conclusion of major concepts, as well as provide feedback on the students' comprehension of presented material. For the edition used within the study, all embedded questions gave immediate feedback on correctness, and some (not all) would provide hints when answered incorrectly. Afterward, some (not all) of these

questions provided detailed solutions. Top Hat recorded participation and correctness scores for all the embedded questions. The Traditional cohort used a static textbook to complete the readings. Though specific sections were assigned to both cohorts to read before class, there was no way to track the Traditional cohort's use during the study as there were no embedded questions within the traditional textbook.

In lecture, after completion of the in-class instructor-led examples, students in both cohorts would then work on Top Hat worksheets in groups. These worksheets had questions pertaining to what was covered in assigned readings, lecture videos, and instructor-led in class examples. These questions also provided immediate feedback on correctness. Teaching assistants and the instructor were available to help students during the class period. The students had a week to complete the worksheet if they were not completed within class. Again, the students' participation and correctness scores were recorded. A previous study shows that rewarding as little as two percentage points toward a student's final grade would encourage the majority of students to complete the assignment [25]. To encourage the Traditional cohort to complete their lecture video questions and Top Hat worksheet questions, their participation score was worth 10% of their final grade. The same was done for the Top Hat cohort, however their participation score also included the embedded questions within their textbook.

To better understand the students' interactions and feelings towards their respective textbooks, end-of-semester surveys were administered through a university-approved survey system, Qualtrics. Student responses provided qualitative data. The survey consisted of three total questions, two being open-ended, with the last question being a combination of closed- and open-ended responses (i.e., a five-point Likert scale). These questions were created by the researchers to gauge the students' feelings toward their interaction and engagement with their respective textbook. Due to the lack of prior studies conducted on this specific topic, there was no relevant literature and/or theories to consult in the creation of the questions. The questions for each textbook are shown in Tab. 1.

The first two open response questions were reviewed using a coding procedure outlined by Creswell [26]. The researchers used an inductive coding scheme [27], meaning the themes were determined only after carefully reviewing the student responses, not before. Two researchers other than the instructor were used to complete this task, as this would help increase the reliability of the results and also minimize any bias that may be introduced. Each reviewer would read through the students' responses to the questions. They would then individually create their own themes with definitions for each question being coded. The two researchers would then meet and compare their themes. They would determine a finalized set of themes with corresponding definitions for each question. Again, on their own, they would re-code the students' responses with the finalized themes and definitions. Finally, they would meet once more to compare the codes they selected for the students' responses for each question. In case of disagreement, a third researcher was used in arbitration to determine the final code assignment. The inter-rater reliability was evaluated by calculating percent agreement in coded responses, and was found to be 96%. This high inter-rater reliability indicates the researchers developed an accurate set of categorical descriptions, and were in agreement on student responses. The numeric responses to the Likert scale within the third question were calculated as an average from all the completed responses.

Table 1: Top Hat and Traditional Textbook Student Survey Questions.

	QUESTION	RESPONSE	*n*	RESPONSE RATE
Top Hat	Q1A: Based on your experiences with the Top Hat textbook, including both the assigned reading and In-class Team Worksheets, do you feel like it helped, hindered, or had no impact on your learning and understanding of the course material? If so, in what aspects? Why?	Open Response	63	86%
	Q2A: Did you find the Top Hat textbook more or less engaging than a traditional engineering textbook? If so, in what aspects? Why?	Open Response	63	86%
	Q3A: On a scale of 1 to 5, with 1 being a very negative impact and 5 being a very positive impact, how has the Top Hat textbook affected your enjoyment/satisfaction with the course? Feel free to comment in an open-ended fashion along with your numeric response.	Numeric and Open Response	67	92%
Traditional	Q1B: Based on your experiences with the textbook, do you feel like it helped, hindered, or had no impact on your learning and understanding of the course material? If so, in what aspects? Why?	Open Response	72	66%
	Q2B: Did you find the textbook more or less engaging than other traditional engineering textbooks? If so, in what aspects? Why?	Open Response	56	51%
	Q3B: On a scale of 1 to 5, with 1 being a very negative impact and 5 being a very positive impact, how has the textbook affected your enjoyment/satisfaction with the course? Feel free to comment in an open-ended fashion along with your numeric response.	Numeric and Open Response	79	72%

Results & Discussion

To see if the interactive, online textbook had any effect on student performance, the grades for the students' first and second midterm examinations, final exam, and final course grade were compared between cohorts and any significant differences were recorded. Before running an independent t-test on the recorded scores, the data was checked for normality, homogeneity of variance, and any significant outliers using IBM SPSS Statistics. The Shapiro-Wilk test was used to assess normality. The tests showed the distributions for final exam and final course grades departed significantly from normality for both the Top Hat and Traditional textbook groups ($p < 0.001$). While this was noted, t-tests were still carried out as the sample sizes were quite large for the Traditional cohort (n = 109) and the Top Hat cohort (n = 73). Since each cohort had a sample size larger than 40, normality was deemed acceptable. [28, 29]. Levene's Test for Equality of Variances was used to check the homogeneity of variance. Both groups passed for each evaluation. Almost every data set had a small number of outliers, but their effects were limited, and performing t-tests was deemed acceptable. In addition, each cohort entering the study had comparable grade point averages (GPAs). The pre-existing average GPAs for the Top Hat and Traditional textbook cohorts were 3.26 and 3.21, respectively. Since all assumptions were sufficiently met, several independent

t-tests were conducted using an alpha value of 0.05. The grades for midterm 1, midterm 2 and the final exam, as well as the overall course grade, were compared between cohorts. Box plots of the data used for each test are shown in Fig. 1. All test results are summarized below in Tab. 2.

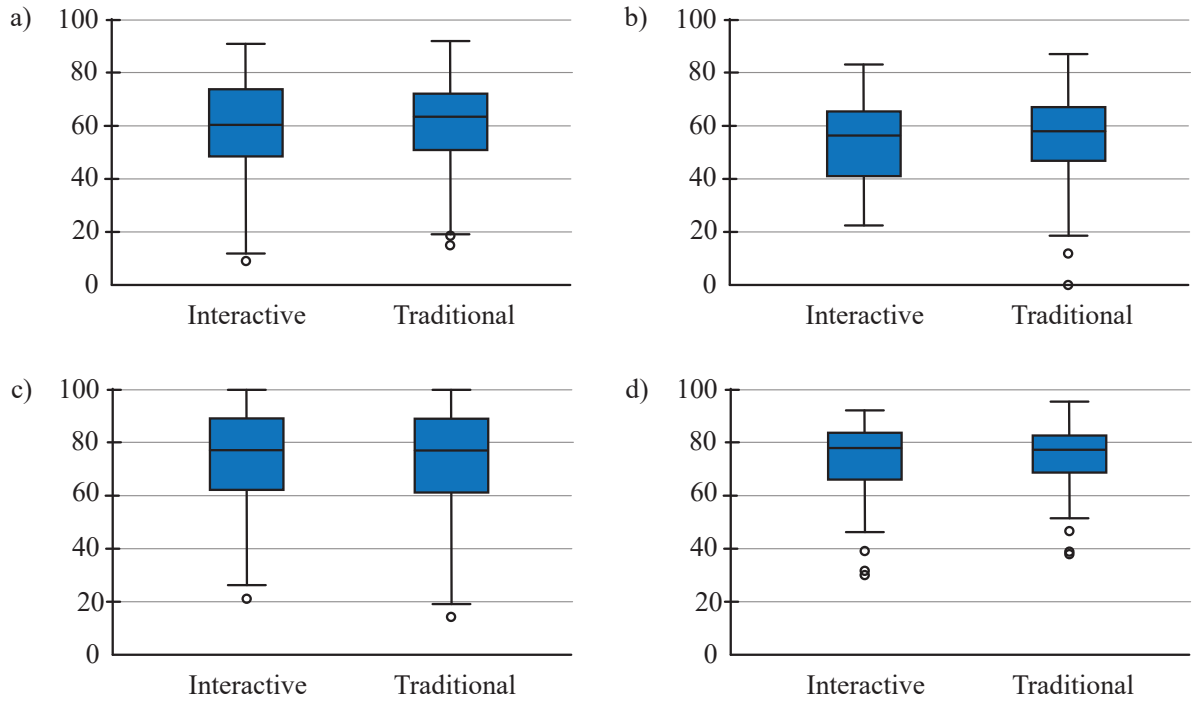

Figure 1: Comparison of a) midterm 1, b) midterm 2, c) final exam and d) course grades between Top Hat and Traditional cohorts.

Table 2: Descriptive Statistics and Comparison of Means of Data Sets

		Group Statistics			Levene's Test for Equality of Variances	t-Test for Equality of Means		Shapiro-Wilk Test of Normality
Assessment	Cohort	n	Mean	σ	Significance	t	One-sided p	Significance
Midterm 1	Interactive	73	58.74	18.67	0.290	-1.058	0.146	0.096
	Traditional	109	61.53	16.58				0.010
Midterm 2	Interactive	73	54.21	16.06	0.629	-0.861	0.195	0.095
	Traditional	109	56.32	16.35				0.060
Final Exam	Interactive	73	72.27	20.25	0.824	-0.163	0.435	< 0.001
	Traditional	109	72.76	19.67				< 0.001
Course Grade	Interactive	73	73.65	13.92	0.200	-0.634	0.264	< 0.001
	Traditional	109	74.86	11.66				< 0.001

After reviewing the results, it is clear that there were no statistically significant differences in performance between the Traditional and Top Hat cohorts. Both groups performed the same across all graded evaluations, having comparable means and standard deviations. This aligns with the results of an earlier study performed by Kecskemety et al. [22], where there was no significant difference in performance between cohorts using interactive and static textbooks.

The coding schemes developed for each question (Q1A, Q1B, Q2A and Q2B) are shown in Tab. 3 and Tab. 4. It is noted Tab. 3 contains the codes for the Top Hat cohort (denoted with an "A" after the question number), while Tab. 4 contains the codes for the Traditional cohort (denoted with a "B" after the question number). The major categories can be broken down by positive or negative connotation. Some codes had both positive and negative connotations, while others were simply positive or negative.

Table 3: Top Hat Textbook Student Survey Questions Coding Schemes.

	CATEGORICAL DESCRIPTION		**CODE**
Q1A	Problems (Positive)		Student liked the problems either from the homework and/or worksheet problems.
	Examples	Positive	Student enjoyed/appreciated or found useful the examples given in the text.
		Negative	Student did not like or found the examples provided unsatisfactory; requested more examples.
	Reading (Positive)		Student mentioned they enjoyed the reading assignments and/or enjoyed the writing style (concise).
	Feedback	Positive	Student thought the immediate feedback was helpful in their learning.
		Negative	Student thought the feedback was unhelpful or not in-depth enough.
	Embedded (Positive)		Student enjoyed the embedded questions that immediately followed the readings.
	General	Positive	Student said something good about it helping their learning.
		Negative	Student said that it did not help, too much time, sig-figs were an issue, etc.
Q2A	Writing (Positive)		Student mentioned it was concise and/or used better language to portray the point.
	Embedded (Positive)		Student enjoyed the embedded questions that immediately followed the readings.
	Feedback (Positive)		Student thought the immediate feedback was helpful in their learning.
	Organization (Positive)		Student found the layout/software easy to navigate, access, and use; organized.
	Practice (Positive)		Student found the given examples, worksheet, and/or homework problems to be engaging.
	More (Positive)		Student mentioned something positive about the text being engaging or interactive in some way.
	Less (Negative)		Student mentioned that they prefer the traditional textbook or that the traditional text was more engaging or better in certain aspects.

Table 4: Traditional Textbook Student Survey Questions Coding Schemes.

	CATEGORICAL DESCRIPTION	CODE
Q1B	Helped (Positive)	Student mentioned anything about the book being useful or aiding them in the course.
	Practice (Positive)	Student mentioned using the text for practice problems and/or examples.
	Did Not Use (Neutral)	Student mentioned that they did not use or used very minimally the text in the course.
	No Impact (Neutral)	Student said the text had no impact on their learning.
	Hindered (Negative)	Student mentioned that the book negatively affected them in some manner.
	Negative (Negative)	Anything bad about the text.
Q2B	More (Positive)	Student mentioned something positive about the text being engaging or interactive in some way.
	Same (Neutral)	Student mentioned that the text is just as engaging as a regular engineering textbook.
	Did Not Use (Neutral)	Student mentioned that they did not use or used very minimally the text in the course.
	Less (Negative)	Student mentioned that they prefer the traditional textbook or that the traditional text was more engaging or better in certain aspects.

No coding was done for the third question (Q3A and Q3B), for the majority of students simply replied with a number in response to the Likert scale. Therefore, the numerical responses to the third question were averaged and are represented as a histogram, as shown in Fig. 4, which will be discussed later. Of the students that did respond, the overwhelming majority simply restated their answers to the two previous questions. The results for the first and second questions are displayed in Fig. 2 and Fig. 3, respectively.

It is interesting to note that the Traditional cohort had a lower response rate on both the first question (Q1B) and second question (Q2B) than did the Top Hat cohort (Q1A and Q2A, respectively), as seen in Tab. 1. The Traditional cohort had a response rate of 66% for Q1B and a 51% for Q2B compared to the Top Hat with a 86% response rate for both Q1A and Q2A. This trend also holds true for the third question.

As seen in panel a) of Fig. 2, the most used code was the General−Positive for Q1A, being assigned 26 times. The second and third highest codes were Problems−Positive and Examples−Positive. They were assigned 13 and 12 times, respectively. A plausible reason as to why General−Positive was assigned so frequently was most students said that the Top Hat textbook was helpful because of the "interactiveness." The authors could infer the only interactive feature the students could be referring to was the embedded questions. However, without a response explicitly identifying what was "interactive," these responses were categorized as General−Positive. As seen in panel b) of Fig. 2, the most assigned code for Q2A was More−Positive (18), followed by Practice−Positive (15), and then Less−Negative (13). The

students appeared to respond positively to the problems supplied through the various methods, and that the problems made the textbook feel more engaging.

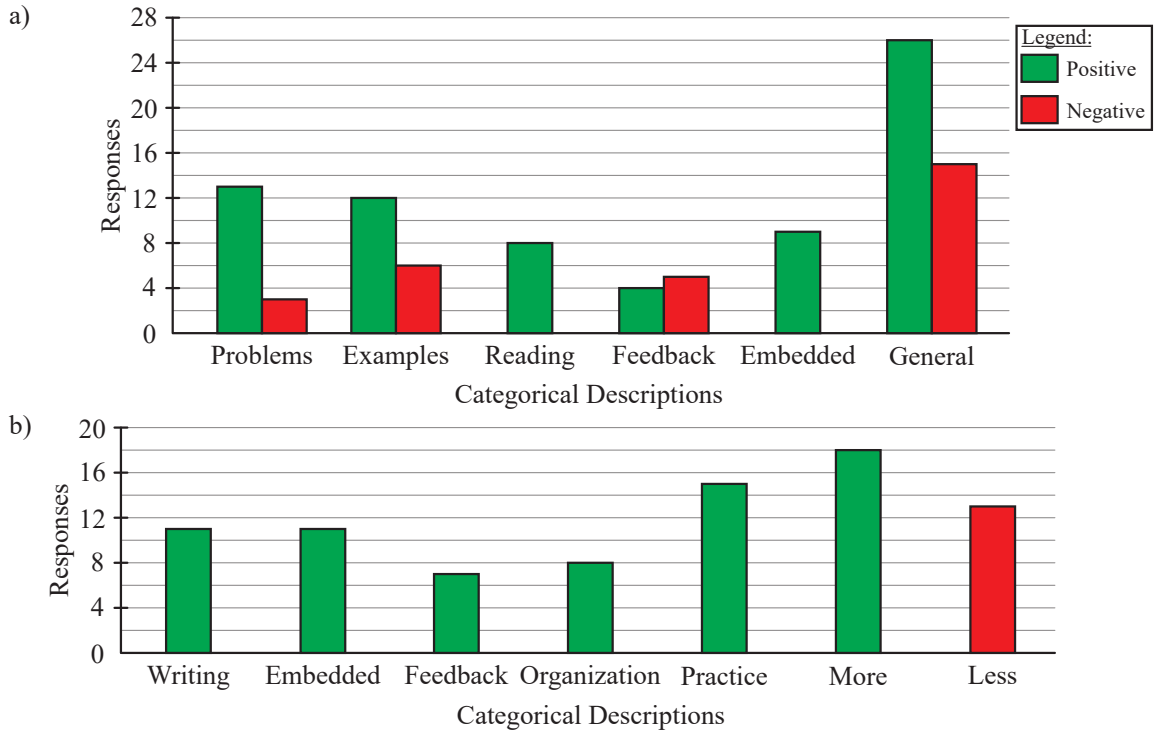

Figure 2: Responses per categorical descriptions for Top Hat textbook: a) Q1A and b) Q2A.

It is evident from Fig. 3 that Q1B had Practice−Positive being coded the most (25). The second and third highest were No Impact−Neutral (18) and Did Not Use−Neutral (16). Though a significant number of students appeared to not have used the traditional textbook or believed it did not have much impact on their learning, the students that did enjoy it did so for the extra practice problems it provided. The three most used codes for Q2B were Did Not Use−Neutral (22), Same−Neutral (15), and Less−Negative (11). The majority of the students that did use the textbook felt that the traditional textbook was equally or less engaging that other engineering textbooks.

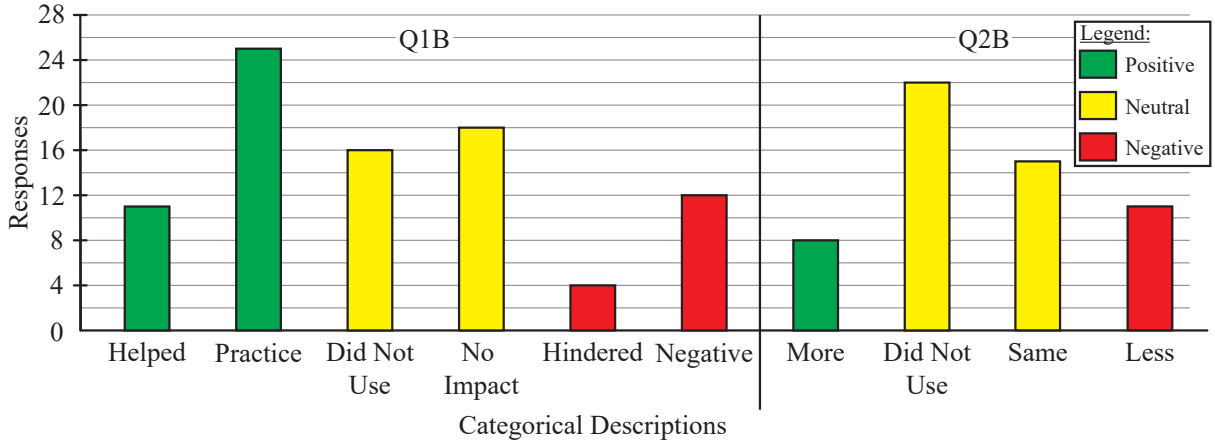

Figure 3: Responses per categorical descriptions for traditional textbook: Q1B and Q2B.

As seen from the coding schemes created, most are rather specific to what the students deemed as a positive or negative part of the textbook (e.g., Feedback or Organization). Some positive or negative responses, however, did not fall into the respective categories. To account for these, the researchers created certain categories to still note the positive or negative responses towards the textbook. If the statement was either too broad or the researchers were unable to identify what the student's response was trying to convey, it would fall into these categories. An example of a General−Positive code from a student's response to Q1A was, "It's helpful." Some responses were not coded as they failed to answer the posed question. For example, for Q2B, "Did you find the textbook more or less engaging than other traditional engineering textbooks? If so, in what aspects? Why?" a student responded with "The textbook my section had to use was a traditional engineering textbook." That response was not coded as it failed to answer any part of the question. In the case of a response not being coded, it was only done so for that question. For Q1A and Q2A, four responses each were not coded. Q1B and Q2B had 10 and 27 responses not coded, respectively, as they failed to answer the questions.

Though the Top Hat textbook had no discernible influence on student performance, namely examination scores and course grade, the students' feelings towards using the interactive textbook appear to be more positive than those who used the traditional textbook. The students who used the interactive textbook had roughly 71% positively coded responses and only about 29% negatively coded responses for Q1A. Q2A had approximately 84% positively coded responses versus 16% negatively coded responses. Meanwhile the traditional textbook had coded responses being 42% positive, 19% negative, 21% No Impact, and 19% as Did Not Use for Q1B. For Q2B the coded responses were 14% positive, 20% negative, 27% Same, and about 40% as Did Not Use. These percentages are calculated using the total number of assigned codes. For example, looking at Q1A there were a total of 101 codes assigned with 72 being positive. This yields the percentage of positive codes assigned as 71% shown above.

Comparing the cohorts, there is a larger percentage of positive codes for the Top Hat cohort than the Traditional cohort. The students in the Top Hat cohort seemed to think their textbook had a beneficial impact on their learning and understanding of course material. The large majority of the Top Hat cohort actually enjoyed the assigned reading assignments noting that it helped keep them on task. This can be seen from a student's response to Q1A, stating:

> *Personally, I found the online textbook to be very helpful. There were example problems in every assigned reading section accompanying the presented information. Also, the embedded questions within the assigned reading motivated me to read the material before every class. This helped me stay on top of the course material, participate effectively in class, and understand what was being [taught] during class time. I also enjoyed the distribution of worksheets, homework, and quizzes via Top Hat. Everything was in a single place, therefore the trouble of losing papers was minimized. The platform was also easy to maneuver. Ultimately, I feel as though I would have done worse in the class if the Top Hat textbook did not exist. It was easy to understand and supplemented the material being taught sufficiently.*

Students seemed to truly appreciate the writing in the interactive Top Hat textbook. Many students made note that the writing was much more concise and straight to the point than a traditional textbook. As seen from a student's response, "More engaging, I feel like the book simplified

things while traditional textbooks over complicate." This is rather striking, for the page count of the Top Hat textbook was approximately 320 pages, whereas 312 pages of the traditional textbook were covered. Another student responded to Q1A noting:

> *It helped my understanding of the material. The practice problems were clear and concise, working through them helped me understand the concepts much better. It aided in my understanding of the concepts and develop basic algorithms to tackle various types of problems. The order of the material we learned also helped me understand the topics were related to one another.*

Seeing as the interactive Top Hat textbook is still being developed, it was no surprise that there were negatively coded responses. An important note is that the majority of the negative comments made within the Top Hat cohort were due to the use of significant figures. The Top Hat cohort was required to use significant figures throughout the entirety of the course—in the embedded questions within the reading, on the homework and quizzes, and even within the in-class worksheets—whereas the Traditional cohort was not required to use significant figures outside of the section it was taught. This appeared to be one of the major contributors to the negatively coded responses of the Top Hat cohort. Though the Traditional cohort had a lower percentage of negative codes, it is evident a large percentage of coded responses were categorized as No Impact or Did Not Use. These percentages associated with lack of usage align with the study done by Berry et al. [13].

Using a Likert scale in Q3A and Q3B allowed for the gathering of quantitative data on the students' perceptions toward their textbook and overall satisfaction and/or enjoyment with the course. A value of unity on the scale corresponds to a very negative impact while five corresponds to a very positive impact. As seen in panel a) of Fig. 4, the Top Hat cohort had an average response of 3.46, with a right-shifted distribution of responses. Of the 67 respondents, 32 responded with a value of less than three, while 35, or approximately 52%, responded with a value of three or greater. Conversely, as seen in panel b) of Fig. 4, the Traditional cohort had an average of 3.04 with a left-shifted distribution of responses. Of the 79 respondents, 56 responded with a value of less than three, while only 23, or 29%, responded with a value of three or greater. The median for the Top Hat cohort was 3.75 while that of the Traditional cohort was 3.00. It is also noted the average value of the Top Hat cohort's responses is 0.42 higher than that of the Traditional cohort's responses.

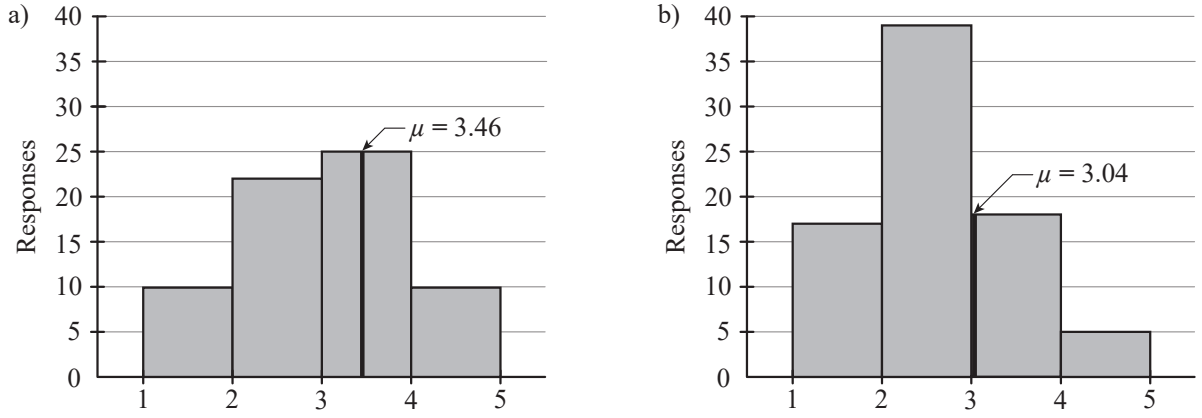

Figure 4: Comparison of a) Q3A and b) Q3B.

Conclusion

An online, interactive textbook was developed to reduce common issues students have with typical collegiate textbooks, namely cost, verbosity, lack of engagement, and a subsequent lack of usage. The goal was to make a cost-effective textbook that was more accessible and promoted student engagement. This was accomplished through the use of embedded questions within the assigned reading, which provided immediate feedback on understanding. It was hypothesized that the interactive textbook would have a positive correlation with student performance in the course. This, however, was not evident in the data after conducting t-tests, as there were no statistically significant differences found between the Top Hat and Traditional cohorts' performance on multiple formal assessments. There was, however, a clear difference in the qualitative results. The students using the online, interactive Top Hat textbook stated that the textbook had a positive impact on their learning and satisfaction. The Top Hat cohort also felt significantly more engaged with their textbook than the Traditional cohort. Although there was no distinguishable improvement in performance, there was also no decrease in performance through the use of the Top Hat textbook. Considering the students' mostly positive perceptions of the Top Hat textbook, and the drastically reduced cost of the Top Hat textbook in comparison to the traditional textbook, the Top Hat textbook has been deemed a viable replacement for the traditional textbook.

An important note about the presented study is its limited scope which may be a contributing factor to a lack of change in student performance. It is well documented that a portion of students do not use their textbooks. This was a motivating factor in the creation and implementation of the interactive textbook. The Top Hat cohort was required to use their textbook via a participation grade. However, this does not mean the students were using the textbook in an earnest manner. The students could have very easily skipped the reading and just selected random answers to gain the points needed for the participation grade. Top Hat did track both participation and correctness, but these questions were not graded on correctness in hopes of providing low-stakes engagement. Currently, the authors did not quantify student use of the textbook as it is intended. This possible misuse may be the reason that even though using the textbook was required, the students' performance was equal to that of the Traditional cohort.

With feedback from the students, the researchers plan to implement changes to the interactive Top Hat textbook as to address students' needs and concerns. The first major change will be to limit the use of significant figures outside of the corresponding section. This is because although significant figures are important to know and use, their level of use varies considerably across different industries. The second revision will be to program hints and detailed explanations into all problems within the textbook and used on the Top Hat platform. The desire for hints and explanations for all questions was mentioned numerous times by the students surveyed, even for students using the traditional textbook. One of the final transformations will be creating more in-depth yet guided problems within the textbook. Students noted a discrepancy between the relatively easy embedded questions within the textbook and the rather difficult yet guided questions administered via the in-class worksheets.

Moving forward, more studies regarding the interactive textbook will be conducted. There may be too many confounding variables that prevent the observation of a correlation between textbook usage and student performance. In the future, the researchers plan to conduct another study, again

with two cohorts, one using the Top Hat textbook and the other the traditional textbook. Each group will take a pre-test on a specific topic, then will read the corresponding sections from their respective texts. Following the reading, they will take a post-test. It will be possible to examine the differences between the groups' pre- and post-test scores to better compare the influence the textbook has on student performance. Another study will have a cohort read and use both textbooks, and then answer survey questions regarding each. These will also be followed up with interviews in an attempt to gather more insightful information. The researchers plan to further investigate how the students interact with the embedded and homework questions. Top Hat records the participation and the correctness while also providing a time stamp for each attempt. This will allow the researchers to see if students are just answering for points or if they are making multiple attempts in hopes of successfully working through problems. This will also allow the researchers to determine what percentage of students are using the interactive textbook as intended and which are not.

In terms of impact, the findings of this study are not limited only to the further development and implementation of this curriculum-specific interactive, online textbook at the authors' university. Any instructor that is interested in either adapting this textbook to their existing course, building a course around this existing textbook, or authoring their own textbook, can be guided by these findings. Specifically, students overwhelmingly enjoy compartmentalized learning, and found the textbook contributed positively to their satisfaction and/or enjoyment with the course.

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