Exploring the Impact of a MATLAB Programming Interactive e-Textbook in a First-Year Engineering Course

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Introduction

The use of electronic or e-textbooks continues to find greater acceptance and enjoy increased prevalence as in 2019, most undergraduate students have functioned in a digital world for the greater part of their lives. This has been occasioned in part, by improved technology as well as the corresponding increase in availability or access. E-textbooks are being introduced across several disciplines including engineering and medicine. Öhrn et al [1] compared the use of traditional textbooks vis-à-vis interactive computer learning for medical residents studying the pharmacology and clinical management of neuromuscular block. In this work, the computer platform was carefully designed with an interactive, problem-based approach. Medical residents using this platform for learning significantly outperformed their counterparts who used the traditional textbook. Edgcomb and Vahid [2] further lend support for the use of interactive textbooks but caution that it is not enough to merely make a traditional textbook available in digital format. Rather, it is imperative that the design of the platform be written intentionally to a web audience. In essence, the literature suggests that e-textbooks have many advantages over traditional paper books. The portability of the books allows them to be accessed anywhere [3]. Also, these platforms include multimedia and interactive elements such as animations, videos, and practice problems [3-5]. Additionally, e-textbooks can oft times be less expensive for students [3]. E-textbooks sometimes allow for instructor customization of the order and presentation of the material. While studies have showed that comprehension between electronic and print median are similar [6], it is anticipated that the interactive nature of some e-textbooks would lead to an increase in grades due to the increased practice as has been seen in research [7].

The course that is the context for this study is the first semester course in a two-course required first-year engineering sequence. The first semester focuses on problem solving through the use of computer tools including Microsoft Excel and MATLAB programming. Prior to 2018, all sections offering this course used a recent edition of "MALAB: An Introduction with Applications" by Gilat as the textbook for MATLAB instruction and there was no textbook for the Excel portion of the course. However, in the Spring 2018 semester, pilot sections of the course used zyBooks, an interactive e-textbook, for the MATLAB portion of the course. This was expanded to all sections in Autumn 2018 and the e-textbook was also customized to include chapters on spreadsheets to provide instruction for the Excel part of the course.

It is during this full implementation of the e-textbook that we seek to study the impact on student grades and perceptions of the book. This study will be the first step to answering the following research questions:
- *What is the impact of using an electronic textbook compared to a standard textbook, on student grades?*
- *What are the student perceptions of the electronic textbook and how could it be implemented more effectively?*

This paper is the first study we are conducting to address elements of these questions.

Methods

This Fundamentals of Engineering I course focused on problem solving through MATLAB and Excel. It includes a variety of assessment types for which the grade categories and the percent of the overall grades can be seen in Table 1. The assignments and categories did not change much from Autumn 2017 to Autumn 2018. One change unrelated to this study was the move from Journals to Discussion Boards. This has no impact on this study as this was a participation reflection assignment score and the only difference was the method of collecting the reflection. The other change that is of interest to this study is that in-class pop quizzes were replaced with zyBooks participation scores. Previously, in-class pop quizzes were administered to reinforce the reading that was assigned for that day from the standard textbook. This was replaced with completing the zyBooks participation activities. These activities require the students to click through the assigned sections of the book and view any animations and completed low-level activities in the book. All other aspect of the course remained similar and grade distributions will be investigated.

Table 1: Course Grade Categories and Percentages

Autumn 2017		Autumn 2018	
Class Assignments	**29%**	**Class Assignments**	**29%**
Pop Quizzes	6%	zyBooks Participation	6%
Application Assignments	23%	Application Assignments	23%
Lab Assignments	**27%**	**Lab Assignments**	**27%**
Pop Quizzes	6%	Pop Quizzes	6%
Lab Documentation	12%	Lab Documentation	12%
Presentations	3%	Presentations	3%
Software Design Project	6%	Software Design Project	6%
Exams	**40%**	**Exams**	**40%**
Midterm 1	8%	Midterm 1	8%
Midterm 2	12%	Midterm 2	12%
Final	20%	Final	20%
Participation	**4%**	**Participation**	**4%**
Team Evaluations	2%	Team Evaluations	2%
Journals	2%	Discussion Boards	2%

At the end of the semester students are given a final end of course evaluation. In both Autumn 2017 and Autumn 2018, students were asked "During the MATLAB part of this course, on average how many hours per week did you spend using the MATLAB textbook?" The results to this question were averaged for each survey and will be presented in the results section.

Additionally, in the Autumn 2018 end of course survey, students were also asked "What is one thing you enjoyed about the zyBooks textbook in [course number]?" and "What is one [thing] that you think could be improved about the zyBooks textbook experience in [course number]?" The survey responses were then put in a randomized order and a small sample was analyzed by one researcher. An open-coding method was used and common themes from this sample were then made into codes. The same researcher then continued to analyze a total of 302 responses from each question. 302 responses were chosen to have an appropriate sample size with a 95%

confidence interval. Each survey response was read and coded based on if the response emulated a given code. A single response could be tagged with multiple codes. After each question was analyzed, the number of responses that were tagged with each code was aggregated.

Results and Analysis

Grade Analysis

All elements of the course remained similar from Autumn 2017 to Autumn 2018, however some assignments and assessments changed. The elements shown in this section are from the parts of the course that remained relatively unchanged. These unchanged elements are the Application Assignments, the Midterm 2 Exam, and the Final Exam. Additionally, the overall final grades are shown as well. Each histogram in Figures 1-4 shows the grade distribution of each of these categories, with each section of the histogram corresponding to a letter grade (A, A-, B+, B etc.) based on the standard university grade scheme shown in Table 2.

Based on these histograms and the course averages for each category, there are minimal differences in the Application Assignments, Midterm 2 Exam, and Overall Course grade between the semester that used the traditional textbook and the semester that used the zyBooks e-textbook. The one category that did have a difference was the Final Exam. In this case there was a 2.4% decrease from Autumn 2017 to Autumn 2018. The exam and preparation for the exam was the same in Autumn 2018 as Autumn 2017, however, in Autumn 2017 students had the opportunity to use one problem from the Final Exam to replace a score from their Midterm 1 Exam. This incentive may have changed the study habits for the Final Exam and impacted the data presented here. The overall grades did not change, demonstrating that the new e-textbook did not negatively impact grades, however there was not the anticipated benefit of increased grades.
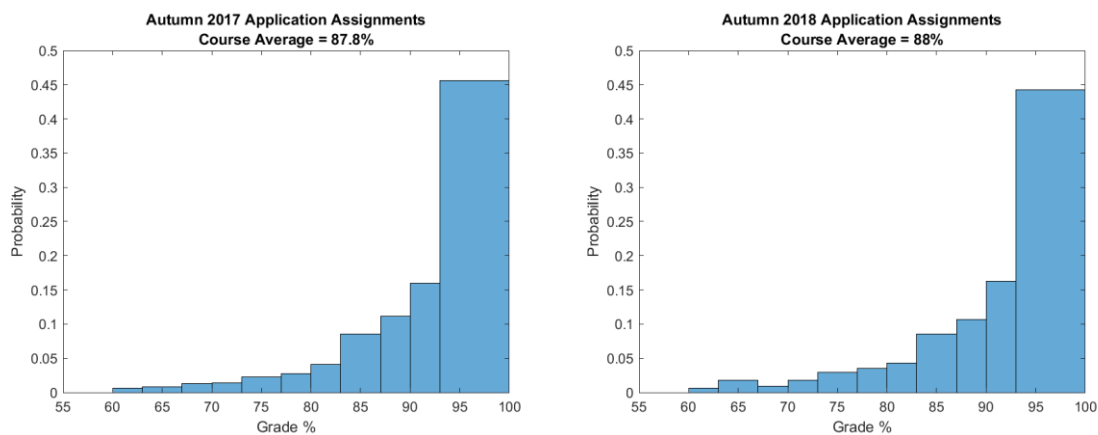

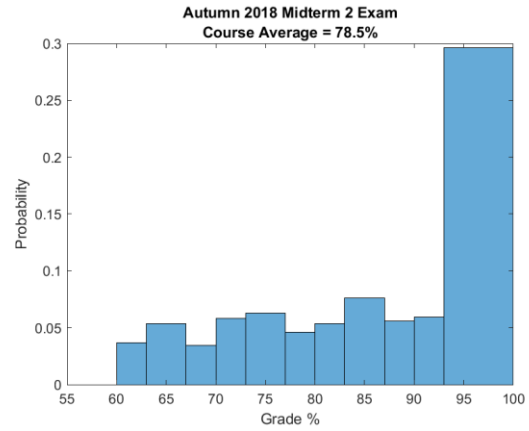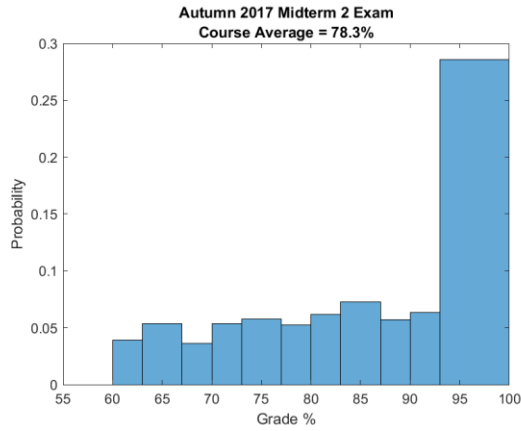Figure 1: Grade Distribution of Application Assignments

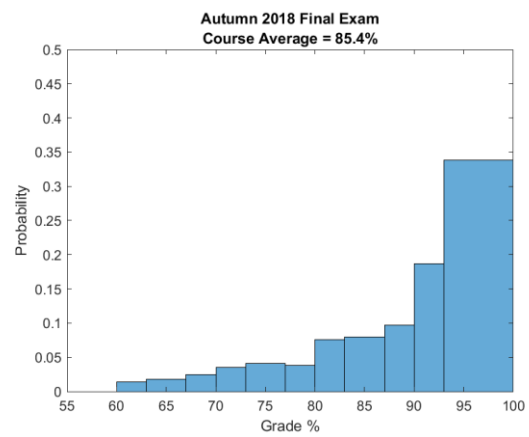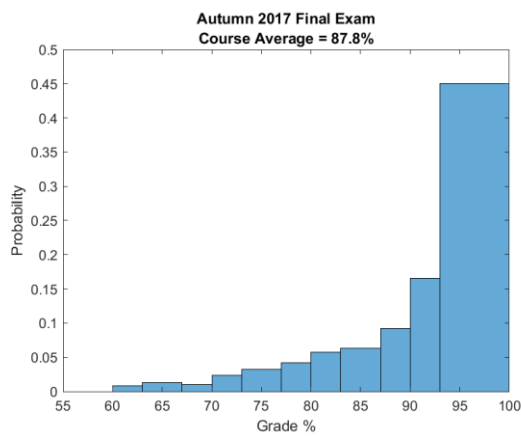Figure 2: Grade Distribution of Midterm 2 Exam
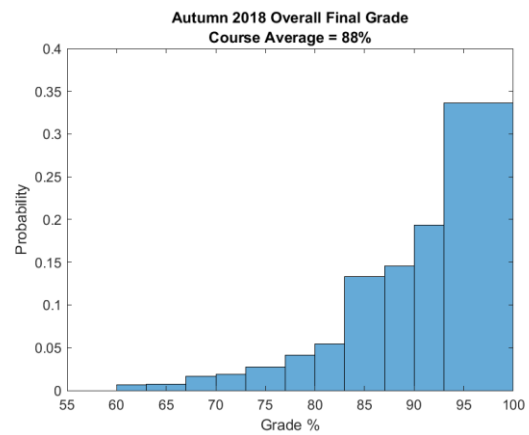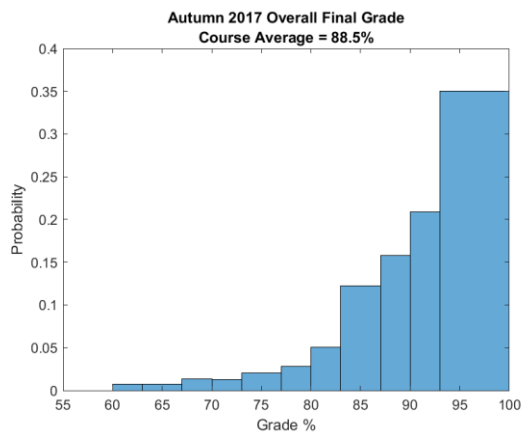

Figure 3: Grade Distribution of Final Exam

Figure 4: Grade Distribution of Overall Final Grades

Table 2: Standard University Grade Scheme

Letter Grade	Numerical Grade
A	93-100
A-	90-92.9
B+	87-89.9
B	83-86.9
B-	80-82.9
C+	77-79.9
C	73-76.9
C-	70-72.9
D+	67-69.9
D	60-66.9
E	<60

Survey Analysis

An end of course survey, administered to students in Autumn 2017 and Autumn 2018, both contained the same question regarding the number of hours spent using the textbook. In Autumn 2017, students were still using the paper textbook. However, students were asked the same question in Autumn 2018, after the implementation of the zyBooks e-book

As seen in Table 3, student usage of the textbook increased by an average of roughly 30 minutes per week after the implementation of the use of the zyBooks e-book. Given the course average remained relatively constant, as seen in Figure 4, even though students spent more time working on their textbook, their grade did not reflect an obvious change.

Table 3: Averages of Student Self-Reported Textbook Reading

	Autumn 2017	Autumn 2018
During the MATLAB part of this course, on average how many hours per week did you spend using the MATLAB textbook? If more than 10, select 10. - Hours per Week	1.62	2.09

Additionally, students from the Autumn 2018 section were were asked two more questions: one regarding benefits of the new textbook and another regarding possible improvements. The codes for each question can be seen in Tables 4 and 5, including a full code definition and sample response that emulates that code. These codes were then used to analyze 302 responses to each question to maintain a 95% confidence level.

Table 4: Code Defintions and Sample Quotes for Improvement Feedback

"What is one [thing] that you think could be improved about the zyBooks textbook experience in [Course Number]?"		
Code	**Definition**	**Sample Response**
Shorten assignments/split up	There should be more, shorter assignments of similar size rather than few, weekly ones.	"Possibly shorter lessons. Some textbook assignments were extremely long."
Abridge/shorten readings	The book was unnecessarily wordy and could explain the same topics in less words and by assigning fewer sections.	"It was really long and too wordy, the PowerPoint slides in class helped so much more because it was simplified and easier to read and comprehend"
Explain difficult topics more	Confusing topics should have more explanation and activities associated with them.	"I thought the textbook could have done a better job explaining topics."
Simplify formatting and interface	The book was difficult to use and/or navigate.	"Make it easier to access" "The inputs were finicky"
Remove	The book should no longer be used.	"The best improvement to zyBooks would be scrapping it altogether."
Nothing/no room for improvement	There are no ways to improve the book.	"Nothing" "The zyBooks textbooks are satisfactory."
Assign less reading	Only assign reading essential to the course.	"The reading is hard to understand, only the activities help"
Integrate with class lectures more	Reference the book in class and integrate it into lecture slides and content.	"Connect it deeper into lecture"
Help with wrong answers	Provide more guidance when an answer is incorrect.	"At the end of assignment, with the practice problems, providing hints for hard problems would be beneficial."
More challenge problems	There should be more challenge problems.	"Make one challenge activity a requirement for each assignment for extra practice and ensure the student has learned the information."
Fewer challenge problems	There should be fewer challenge problems.	"When challenge problems were required it could be very stressful."
Make more engaging	The book is boring and should be more engaging.	"the long assignments got boring and hard to learn from"
Stop showing answers	Answers should no longer be shown without penalty.	"...I requested the answer for every problem so I wouldn't have to actually do the assignment..."
Integrate with canvas better	The book's grading should be better linked to the university's gradebook and assignments should be posted there.	"Link the zyBooks to Carmen so that the grades are updated no matter how you get to zyBooks"
More practice problems	There should be more practice problems in the book.	"more practice problems"
Lower the price	The book is too costly for the benefit.	"Waste of money"
Blank/no response	A student did not respond.	

Table 5: Code Definitions and Sample Quotes for Positive Feedback

Code	Definition	Sample Response
What is one thing you enjoyed about the zyBooks textbook in [Course Number]?		
Helped learn the material	The book helped teach and explain the material.	"Helped to understand confusing material."
Nothing	The book did not provide any help.	"...didn't teach me anything. I learned more from the demos, PowerPoints, and application problems."
Provided practice	The book provided problems to help practice the material.	"I enjoyed the participation activities. I thought they did a good job of preparing me for the class applications and exams. "
Easy to do/grade booster	The assignments were easy to do and boosted my grade.	"It did not penalize you for not knowing an answer." "The assignments that went along with them were fairly simple"
Intuitive to use	The book was easy to use and interact with.	It was easy to operate and understand"
Explains answers to questions	Answers were explained and given to some problems.	"How if you really couldn't figure it out, you could request answer and it would explain why that answer was the correct choice."
Interactive	The interactive aspect of the book made it enjoyable.	"The activities were interactive, it wasn't just reading."
Thorough/in depth	The book went in depth into topic not covered in class.	"I liked that zyBooks covered things not discussed on class"
Provides examples	Example problems and tutorials were helpful.	"The tutorials were very good at getting the point across in a concise and controlled manner."
Online/eBook format	Not having to use a paper textbook was more convenient.	"The ability to interact with it online."
Engaging	The book made rather boring material more engaging.	"Text was engaging."
Blank/no response	There was no response.	

As seen in Table 6, students had a wide variety of suggestions. The most prominent is to reduce the length of reading and participation assignments. Specifically, many students suggested that the assignments could be made shorter, split up more, and have a standardized length rather than having few, large assignments of varying length.

Additionally, while many students found some sections of the book to be too lengthy and recommended shortening the reading assignments, a large number found that the book was not in depth in the difficult topics they wished it was. It seems plausible that material unrelated to the course as a whole was included in the reading assignments, which could be cut while difficult to understand topics that were covered in class did not have in depth explanation in the textbook. Furthermore, unlike with the paper textbook in which students only needed to read sections they were unconfident about, students were forced to read the zyBooks and complete practice assignments regardless of their level of understanding of the material. This could explain student

recommendations to simultaneously increase and decrease usage of the zyBooks in which students confident with the material found it unnecessary while students less confident with the material found it short to explain topics in depth.

Table 6: Qualitative Coding of Student Feedback on Improvements of e-Textbook

What is one [thing] that you think could be improved about the zyBooks textbook experience in [Course Number]?	
Shorten assignments/split up	46
Abridge/shorten readings	46
Explain difficult topics more	27
Simplify formatting/interface	23
Remove	22
Nothing/no room for improvement	20
Assign less reading	19
Integrate with class lectures more	19
Help with wrong answers	14
More challenge problems	12
Fewer challenge problems	11
Make more engaging	9
Stop showing answers	6
Integrate with canvas better	5
More practice problems	5
Lower the price	3
Blank/no response	57
n total =	303
n respond =	246

As seen in Table 7, students had different opinions on the use of zyBooks as many found it a help to learning the material, while some did not find much enjoyment from it. Additionally, many students commented on its easiness and the associated boost in their grade from the assignments, which were graded for completion and showed answers upon request. It is possible that those that found benefit from the books were the users who went through the assignments and tried to answer them independently while those that didn't simply worked to get the completion points.

Table 7: Qualitative Coding of Student Positive Feedback about e-Textbook

What is one thing you enjoyed about the zyBooks textbook in [Course Number]?	
Helped learn the material	58
Nothing	46
Provided practice	38
Easy to do/grade booster	36
Intuitive to use	30
Explains answers to questions	23
Interactive	22
Thorough/in depth	17
Provides examples	17
Online/eBook format	8
Engaging	5
Blank/no response	49
n total =	302
n respond =	253

An examination of the responses to these two questions would suggest that while students seemed to learn a lot from zyBooks, there was room for improvement from their perspective. It should be noted that the capabilities of zyBooks were not exhausted in this initial implementation. Even though the grades from Autumn 2017 and Autumn 2018 were virtually the same, without and with the use of the interactive e-textbook, this was based more on the way that the platform was used given some limitations. It is also entirely possible that some students simply do not learn well from online material and prefer in person lectures or paper textbooks instead. Some students may have learned enough in lecture and thus did not feel like they needed the textbook to understand the MATLAB content covered in this course.

Conclusions and Future Work

Overall, students using the e-textbook did not perform better based on the measured differently in the course with regards to their overall grades and the grades on major exams and assignment categories compared to students in previous years that used a standard textbook. However, despite no grade change, students did report increased weekly use of the e-textbook compared to students who used the standard textbook. Additionally, students offered many suggestions for improvements for use of the zyBooks e-textbook in future years. Some of the feedback can be incorporated in future offerings of the course in different ways:

Implementing the graded use of more "challenge activities" from zyBooks in place of the "participation activities" that are currently assigned. The "challenge activities" allow for students to employ more application of knowledge and can serve as a better bridge between the reading material and the eventual application assignments related to specific modules. This scaffolding effect can make some of the larger assignments less daunting. The main hurdle faced was that zyBooks auto graded this with an all or nothing points award which runs counter to our grading philosophy that awards partial credit.

Reduction in the amount of participation activities that are assigned and making the assignments of uniform length insofar as is possible can help to enhance student experience. The sheer volume of work assigned to students on some weeks discouraged meaningful participation from some students.

Further integration of zyLabs in the course design will allow students to work on problems where they apply knowledge, with appropriate interactive hints for help. This provides a non-threatening environment for students to try working on a solution to the problems assigned, for as many times as needed, without a direct impact on the grade.

Some additional suggestions for improvements such as changing the content would have to be referred to the publisher for redress.

In the future, it would be helpful to study the grades more in depth. While the overall grade distribution was not impacted, a future study plans to look at rubric level detail for each assignment and exam question to see if there are any differences within specific learning objectives that are being assessed. Additionally, course improvements as to how zyBooks is implemented into the course will be made and assessed.

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