

Assessing the Effects of an Interactive Web-native Materials Science Textbook on Student Self-efficacy

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Abstract

Materials science and engineering textbooks are a critical foundation for many engineering disciplines. These texts are used for in-class learning, and as long-term reference content for other courses. Historically, these learning materials have been static textbooks. But for the last several years, there has been increased use of interactive web-native textbooks in engineering courses, including in materials science and engineering. One example is an interactive web-native introductory materials science and engineering textbook (zyBook), which is based on *Fundamentals of Materials Science and Engineering: An Integrated Approach, 6th Edition* by William D. Callister, Jr. and David G. Rethwisch. While static textbooks are restricted to explaining topics using diagrams, lengthy text, and end-of-chapter problems, the zyBook is also able to include animations, learning questions, randomized auto-graded homework problems, and virtual materials science modules. The interactive elements in the zyBook provide students with additional opportunities to engage with the content in order to increase student success and learning. The goal of this paper is to understand the effects of these interactive elements in the zyBook on student self-efficacy.

A survey was administered to 106 students using the interactive web-native textbook (the zyBook) and 135 students using a different online courseware product (WileyPLUS) at a Midwestern university. The students were surveyed about their use of and experience with the zyBook, including the original textbook content as well as the added interactive elements. Students were asked how much time they spent using the zyBook, when they used it (before or after lecture, or both), and whether each type of interactive element contributed to the student's success in the course. They were also asked about the impact of the zyBook, if any, on their confidence in understanding the material and solving engineering problems as well as on their desire to become an engineer. Finally, students were asked how often they felt specific emotions while using the zyBook, such as *interested*, *distressed*, *excited*, and *ashamed*. The student survey data showed that the majority of students reported that the interactive elements contributed to their success in the course and the zyBook increased their understanding of the course content and increased their confidence in solving engineering problems.

Introduction

Self-efficacy is grounded in a large theoretical framework known as social cognitive theory, which states that human achievement depends on interactions between one's behaviors, personal factors, and environmental conditions [1]. In this paper, we will discuss the differences in

students' self-efficacy in the environmental conditions of using two different formats of a textbook and online assessments. The self-efficacy for students utilizing an interactive web-native version of a book (the zyBook) will be compared to that of students utilizing an online courseware product (WileyPLUS) that includes the static electronic version of book and separate autograded online assessments.

Static print textbooks are limited as to how they can convey information and teach the topics to students, and how students can interact with it. Due to these limitations, e-textbooks and interactive textbooks are becoming a more popular choice for instructors. One study looked at the differences in learning between students who could choose between using a traditional print textbook and an electronic version of the same book [2]. The researchers found that students who chose the electronic version of the books for their education courses had significantly higher perceived affective and psychomotor learning than students who chose traditional print textbooks.

Prior research has shown comparisons between print and electronic textbooks to evaluate student preferences and attitudes [3]-[5]. In Chen et al's paper, researchers found that student perceptions and attitudes toward digital technology such as iPads and ebooks were more positive than toward print textbooks [3]. Those researchers found that students using digital technology completed more learning activities and were more engaged in the classroom. In another study, the researchers looked at the impact between print and interactive textbooks and observed that the students preferred the participation activities in interactive textbooks that are not possible in print textbooks [5]. A different study looked at understanding learners' attitudes toward e-books as learning tools [6]. The study found that the most crucial predictor of perceived satisfaction for students is perceived self-efficacy. Data was collected on student attitudes and self-efficacy in the current study, with an overall positive response from the students.

Prior research has also been conducted on the effectiveness of electronic textbooks. In McFall et al's work, the researchers stated that learning activities in electronic textbooks offer new and engaging methods of showcasing the information to students [7]. These engaging methods are not able to be used in print textbooks, but some researchers have shown concerns as to whether the e-tools are effective. One study conducted over multiple years found that even though the use of e-textbooks has increased, e-textbooks are not always effective [8]. Thus, more research is needed on the effectiveness of e-textbooks. The main focus of the current study is the effects of a materials science and engineering zyBook on student self-efficacy, compared with the effects of a static materials science e-textbook combined with online assessments. Prior research has shown the impact of interactivity on student learning and engagement. In Gyllen et al's paper, the authors found that interactivity in an engineering textbook led to higher grades and gave students more opportunities to practice [9].

Some of the questions asked in the student survey were created specifically for this survey, and some questions came from already validated surveys. One of the questions used in the survey is the Positive and Negative Affect Schedule (PANAS) scale which asks students to pick an emotion they are feeling from provided options. The PANAS scale has been shown to be highly internally consistent, largely uncorrelated, and has been validated. Therefore, the PANAS scale is a valid scale to use in our survey [10]. Other questions in our survey relate to students' self-efficacy. Prior research has validated and found that there is a strong relationship between students' self-efficacy and success in their major [11]. Therefore, the potential impact of the zyBook on students' self-efficacy was an important focus of this current study.

Self-efficacy has also been shown to be a good predictor of student success specifically among undergraduate engineering students [12]-[13]. Even in cases where performance is not factored into predicting student success, students with positive levels of self-efficacy are more likely to persist in engineering [13]. Thus, learning tools that improve students' self-efficacy have value. One such tool is interactive textbooks. Prior research has been conducted connecting self-efficacy to active e-book use. In Chen et al's paper, the researchers looked at student's self-regulated learning and self-efficacy in two different courses with one of the courses using an interactive book, BookRoll, and another course not using BookRoll [14]. They found that students using BookRoll had higher self-regulated learning and higher self-efficacy. The students' online e-book reading behaviors included attaching bookmarks, adding/deleting markers, attaching/removing/editing memos, and slide switching (next/previous/jumping).

While the literature has shown a positive impact on self-efficacy when students use e-textbooks and interactive e-textbooks, these results have not been tested in engineering courses. Thus, this work aimed to answer *How does the materials science and engineering zyBook affect student self-efficacy?* Since a student's perceived self-efficacy is connected to their attitudes, emotions, and satisfaction when using an e-book, some additional research questions considered were *What is the impact on a student's level of excitement and inspiration by using the materials science zyBook compared with a static e-textbook and online assessment in WileyPLUS?* and *How are emotional factors, like distress and frustration, affected?*

Methods

An end-of-semester survey was completed by 106 students using the materials science and engineering zyBook that includes interwoven online assessments during the Spring 2023 semester at a Midwestern university. The survey was also taken by 135 students at the same Midwestern university using WileyPLUS which includes a static e-textbook (based on *Fundamentals of Materials Science and Engineering: An Integrated Approach, 6th Edition* by William D. Callister, Jr. and David G. Rethwisch) with separate online assessments. There were two different sections of the course taught during the Fall 2023 semester consisting of 99

students in the larger section and 36 students in the smaller section. Each of the three sections was taught by a different instructor. The classifications and majors of the students who responded to the survey in Spring 2023 and Fall 2023 can be seen in Table 1 and in Appendix A, respectively. Some students elected to report multiple majors. Although this demographic data was collected, the sample size was too small to do detailed analysis of different groups by classification or major.

TABLE 1: Spring and Fall 2023 Course Student Classifications

Class	Number of Students in Spring 2023 (N=106)	Number of Students in Fall 2023 (N=135)
Freshmen	74	26
Sophomores	14	57
Juniors	7	29
Seniors	8	20
Fifth-year Seniors	3	2
Other	0	1

The survey included questions for students about how much and when they used the zyBook/WileyPLUS, such as *Did you use the zyBook/WileyPLUS before or after lecture?* and *Weekly, how much time did you spend using the zyBook/WileyPLUS?* The survey also included 5-point Likert scale questions with 1 being strongly agree and 5 being strongly disagree that related to the students' usage of and attitudes toward the zyBook/WileyPLUS. These Likert scale questions included:

- *When I got stuck on a homework problem the zyBook/WileyPLUS helped me figure it out;*
- *When using the zyBook/WileyPLUS, I was usually able to understand the concepts being taught;*
- *The zyBook/WileyPLUS increased my confidence in understanding the course material;*
- *The zyBook/WileyPLUS increased my confidence in solving engineering problems.*

Students were also asked about how often they felt certain feelings and emotions when using the zyBook/WileyPLUS. These feelings and emotions included interested, distressed, excited, ashamed, inspired, nervous, determined, frustrated, proud, afraid, and enthusiastic.

The survey results on the Likert scale items for the students using the zyBook were compared to the results for the students using WileyPLUS by performing a one-tailed t -test. The Spring 2023 results were compared to a combination of both sections in the Fall 2023 semester. To check the results, a one-tailed t -test was also run comparing the Spring 2023 student responses to the responses of each Fall 2023 course individually. Those results are included in Appendix A. The p -values were obtained for each Likert scale item and for each course comparison. The p -values were compared to an α -value of 0.05 to test for statistical significance. The Cohen's d effect size was also calculated to show how much of a difference existed between the responses of the students using the zyBook and the students using WileyPLUS. In general, a Cohen's d of around 0.2 is considered a small effect size, while 0.5 is considered a medium effect size and 0.8 is considered a large effect size.

The survey results for the PANAS scale questions about emotions were also analyzed. Each response was assigned a number (1 = A few times or not at all, 2 = Occasionally (25% of the time), 3 = Quite often (50% of the time), 4 = Very often (75% of the time), and 5 = Most of the time). A one-tailed t -test was used to compare the student responses from the Spring 2023 course to the student responses from the Fall 2023 courses combined. To check the results, a t -test was also run to compare the Spring 2023 results to each of the Fall 2023 courses individually. The p -values from the t -tests were compared to an α -value of 0.05 to test for statistical significance. The Cohen's d effect size was also calculated to show the scale of the difference between the students using the zyBook and the students using WileyPLUS.

Results

For the Likert scale item *When I got stuck on a homework problem the zyBook/WileyPLUS helped me figure it out*, there was a statistically significant difference between the mean of the students using the zyBook ($\mu=1.71$) and the students using WileyPLUS ($\mu=2.54$) that included the e-text and an online homework system ($p < 1.71e-11$, Cohen's $d = 0.9$). A graph of the students' responses to this Likert scale item for each choice is included below in Figure 1.

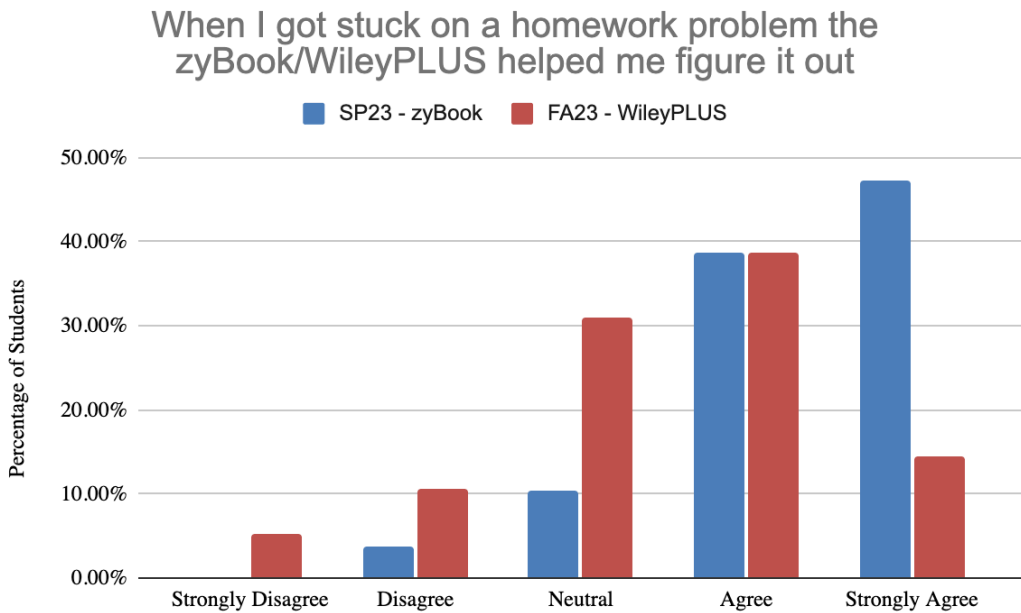


Figure 1: Student Responses for the Likert Scale Item *When I got stuck on a homework problem the zyBook/WileyPLUS helped me figure it out.*

The Likert scale item *When using the zyBook/WileyPLUS, I was usually able to understand the concepts being taught* also resulted in a statistically significant difference in the mean between the Spring 2023 ($\mu=2.12$) and Fall 2023 ($\mu=2.45$) students ($p < 8.5e-4$, Cohen's $d = 0.42$). A graph of student responses to this Likert scale item for each choice is included below in Figure 2.

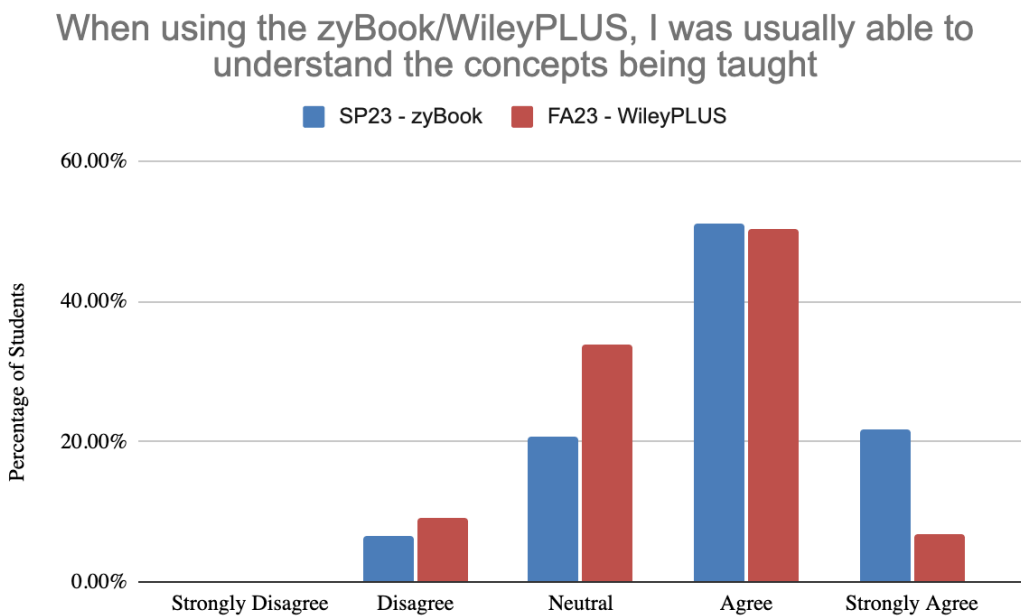


Figure 2: Student responses for the Likert Scale Item *When using the zyBook/WileyPLUS, I was usually able to understand the concepts being taught.*

For the statement *The zyBook/WileyPLUS increased my confidence in understanding the course material*, a statistically significant difference was found in the mean between the Spring 2023 ($\mu=1.97$) and Fall 2023 ($\mu=2.26$) students ($p < 0.0019$, Cohen's $d = 0.38$). A graph of student responses to this Likert scale item for each choice is included below in Figure 3.

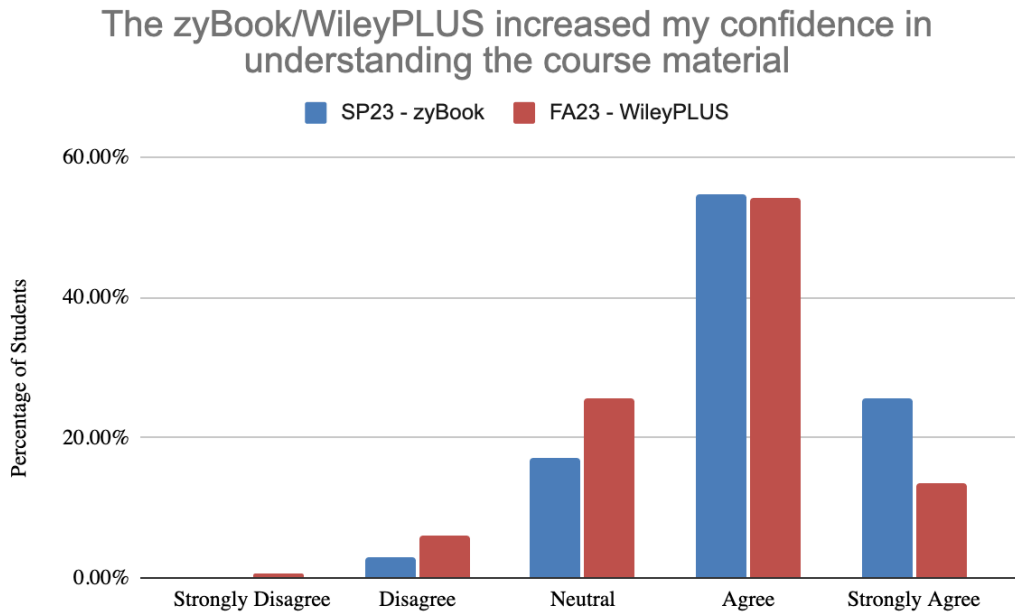


Figure 3: Student responses for the Likert Scale Item *The zyBook/WileyPLUS increased my confidence in understanding the course material.*

The statement *The zyBook/WileyPLUS increased my confidence in solving engineering problems* also resulted in a statistically significant difference between the mean of the students using the zyBook (Spring 2023, $\mu=2.11$) and the students using WileyPLUS (Fall 2023, $\mu=2.59$) ($p < 1.28e-5$, Cohen's $d = 0.56$). A graph of student responses to this Likert scale item for each choice is included below in Figure 4.

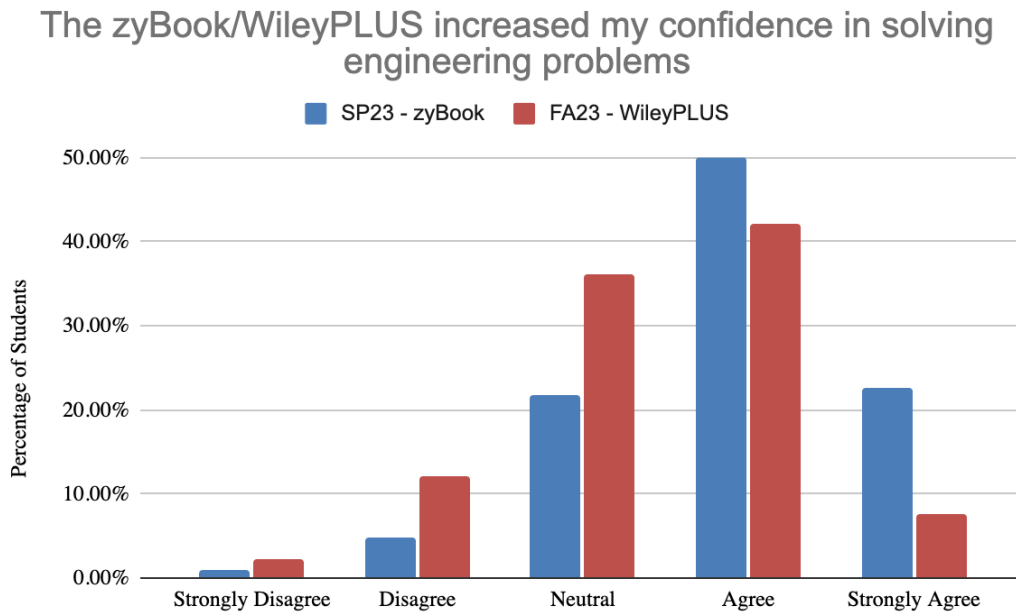


Figure 4: Student Responses for the Likert Scale Item *The zyBook/WileyPLUS increased my confidence in solving engineering problems.*

A statistically significant difference was found on the PANAS scale questions for the feelings excited ($p < 0.0068$, Cohen's $d = 0.33$) and inspired ($p < 0.031$, Cohen's $d = 0.25$) when comparing the students who used the zyBook ($\mu=2.05$ for excited and $\mu=2.09$ for inspired) and the students who used WileyPLUS ($\mu=1.75$ for excited and $\mu=1.84$ for inspired). Graphs of the student responses for excited and inspired are included below in Figure 5 and Figure 6, respectively.

How often did you feel excited when using the zyBook/WileyPLUS?

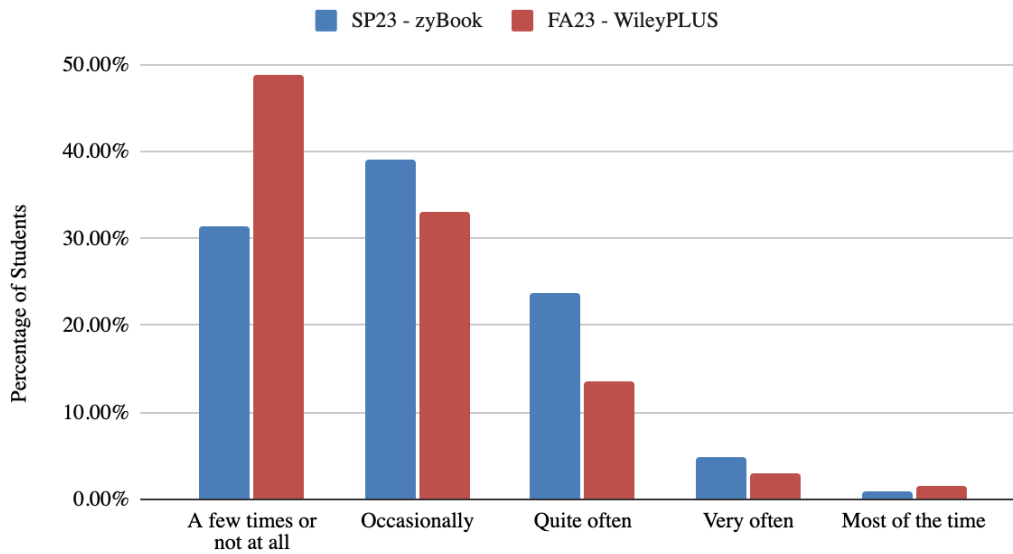


Figure 5: Student responses for the PANAS scale question about feeling **excited**.

How often did you feel inspired when using the zyBook/WileyPLUS?

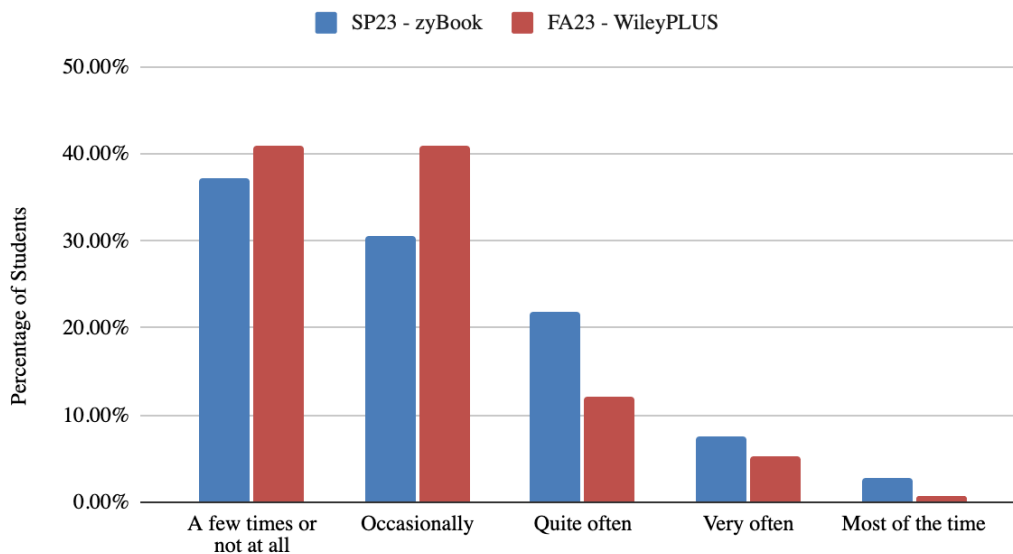


Figure 6: Student Responses for the PANAS scale question about feeling **inspired**.

A summary of the results of the *t*-tests and Cohen's *d* calculations for each of the Likert scale statements and PANAS scale emotion questions are included below in Table 2. A table which

includes the results comparing the Spring 2023 student responses to each individual section from Fall 2023 is included in Appendix B.

TABLE 2: Summary of *t*-test and Cohen's *d* Results for Survey Questions

Statement/Question	<i>p</i> -value	Cohen's <i>d</i>
When I got stuck on a homework problem the zyBook/WileyPLUS helped me figure it out.	1.71e-11	0.9
When using the zyBook/WileyPLUS, I was usually able to understand the concepts being taught.	8.5e-4	0.42
The zyBook/WileyPLUS increased my confidence in understanding the course material.	0.0019	0.38
The zyBook/WileyPLUS increased my confidence in solving engineering problems.	1.28e-5	0.56
How often did you feel excited while using the zyBook/WileyPLUS?	0.0068	0.33
How often did you feel inspired while using the zyBook/WileyPLUS?	0.031	0.25

Discussion and Limitations

When I Got Stuck On A Homework Problem the zyBook/WileyPLUS Helped Me Figure It Out

Although the survey results for the Fall 2023 students who used WileyPLUS that included an e-textbook and online assessments were positive (14.4% strongly agree and 38.6% agree), a higher percentage of students average in the Spring 2023 semester reported that the zyBook helped them to figure out a homework problem on which they were stuck (47.2% strongly agree and 38.7% agree). Because both the zyBook and the e-textbook included the same text, the large effect size of 0.9 makes it clear that the added interactive elements helped the students. It is important that students were able to use the zyBook when they got stuck instead of having to use an outside resource, such as searching for information in a different book or using the internet to find the solution to the homework problem. Students often don't know what they don't know. They struggle with what to look for in a textbook to find relevant information to solve a specific problem. While having the relevant content available in the same viewing field as the problem advantageously lowers cognitive load for the zyBook as compared to WileyPLUS, the large effect size is not likely due to this difference alone. The higher effects for understanding concepts and confidence in understanding concepts indicate that the interactive elements have an impact on students' learning, and subsequently, their ability to solve homework problems.

When Using the zyBook/WileyPLUS, I Was Usually Able To Understand the Concepts Being Taught

The results for this Likert scale item were positive for both groups of students, with the majority of students in the Fall 2023 course either agreeing (50.4%) or strongly agreeing (6.8%) that they were usually able to understand the concepts being taught. However, a higher percentage of students using the zyBook either agreed (50.9%) or strongly agreed (21.7%) with the statement. Again, the added interactive elements can explain the moderate effect size difference in the understanding of the students who used the zyBook and the students who used WileyPLUS. The nature of the interactive elements may also contribute to the difference: animated illustrations, graphs and example problems that reduce cognitive load by allowing students to view and process just a portion of the information at a time; and interactive questions with feedback that address misconceptions.

The zyBook/WileyPLUS Increased My Confidence In Understanding the Course Material

The majority of students in the Spring 2023 course and the Fall 2023 courses reported that the zyBook/WileyPLUS increased their confidence in understanding the course material. However, a higher percentage of students in the Spring 2023 class who used the zyBook strongly agreed (25.5%) or agreed (54.7%) with the statement than in the Fall 2023 class who used WileyPLUS (13.5% strongly agreed and 54.1% agreed). As previously stated, self-efficacy is a good predictor of student success for undergraduate engineering students [12]-[13]. Students with positive levels of self-efficacy, such as is represented by this higher level of confidence in understanding the course material, are more likely to persist in their engineering major.

The zyBook/WileyPLUS Increased My Confidence In Solving Engineering Problems

Students in the Spring 2023 course and in the two Fall 2023 courses reported that the textbook or courseware increased their confidence in solving problems, but there was stronger agreement with the statement from the students in Spring 2023 (22.6% strongly agreed and 50.0% agreed) compared to the students in Fall 2023 (7.5% strongly agreed and 42.1% agreed). Because problem solving is so important in engineering, increasing confidence in solving engineering problems should be a major focus of any instructional material. The moderate effect size for this Likert scale statement shows that the interactive elements in the zyBook have a positive impact on student self-efficacy in solving engineering problems. Many of the animations, conceptual questions, and other interactive activities are specifically designed to show students how to solve problems. In this zyBook in particular, the example problems that existed in the textbook were turned into interactive animations that showed students how to solve the problem step-by-step. Visual elements were also often added to connect the values in the example problems to where the values come from in the figure, image, or diagram.

PANAS Scale Emotions

Students in the Spring 2023 course who all used the zyBook reported feeling excited and inspired more often on average than the students in the Fall 2023 courses who all used WileyPLUS. In Spring 2023, 68.5% of students reported feeling excited and 62.9% of students reported feeling inspired at least 25% of the time when using the zyBook. Comparatively, only 51.1% of students reported feeling excited and only 59.1% of students reported feeling inspired when using WileyPLUS. These results are consistent with the positive feelings that students experienced towards learning when interactive e-textbooks are used over traditional print textbooks (see [2]). While it has been known that students respond with positive effects (qualitatively) to technology [2]-[3], the difference here is that the results are quantified and demonstrated for specific feelings of excitement and inspiration. Feeling more excited and inspired while using the zyBook more so than using WileyPLUS may lead students to have an increased desire to continue in the course and in their major. Students who feel more excited and inspired might also put in more time and effort in the course, possibly resulting in better performance in the course and other courses in their major.

Limitations

This study was conducted over two semesters at a single university in three sections each taught by a different professor. Because of this, there may have been confounding variables that could have affected the student responses to the survey questions. Participation in the study was voluntary and although bonus points were offered to students who completed the survey, not all students in the three sections completed the survey. It is possible that the responses from the students who did not participate in the survey might have affected the results. However, the number of students who did not complete the survey in each section was very small (3 out of 109 students for Spring 2023 and 37 out of 172 students for Fall 2023), especially when compared to the number of students in the classes.

There are some other differences between the zyBook and WileyPLUS in terms of overall accessibility (such as alt text), navigation tools, and general presentation that contribute to a student's overall experience and can be a confounding variable in students' self-efficacy responses. Additionally, we did not explicitly screen for students who had taken the class before, which may affect student self-efficacy.

Conclusions and Future Work

WileyPLUS did positively affect student self-efficacy, but the zyBook clearly had more of an effect on the students' belief in their ability to understand the concepts in each section, to complete homework problems when they get stuck, their confidence in understanding the course material, and in solving engineering problems. The zyBook also made students feel excited and inspired more often than the students who used WileyPLUS.

Because the primary difference between the zyBook and the e-textbook that is included with WileyPLUS is the addition of the interactive elements, the differences in self-efficacy and positive emotions are likely related to those interactive elements. Having access to interactive animations, various concept questions with explanatory feedback that address misconceptions, and clear solutions allows the students to use the zyBook as a true learning resource, as opposed to only accessing it to do the homework, as several students reported doing with WileyPLUS.

The work done for this study will continue in future semesters at the same university, as the same survey will be administered to students using the zyBook in one section and students using WileyPLUS in another section. The survey will also be administered to students using the zyBook at other universities to show whether or not the positive effects on self-efficacy are limited to a single semester at a single university. The survey has also been administered to students using zyBooks in other subject areas in engineering across multiple universities, and those results will be analyzed and compared with these results to determine if the same effects on student self-efficacy are repeated in these other contexts.

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Appendix A

TABLE A1: Spring and Fall 2023 Course Student Majors

Major	Number of Student Responses in Spring 2023 (<i>N</i> =116)	Number of Student Responses in Fall 2023 (<i>N</i> =147)
Aerospace Engineering	2	3
Biomedical Engineering	2	4
Chemical Engineering	3	9
Civil Engineering	7	18
Computer Engineering	1	2
Electrical Engineering	6	11
Environmental Engineering	1	1
Industrial Engineering	0	1
Materials Science and Engineering	5	9
Mechanical Engineering	83	77
General Engineering	0	1
BSE	1	0
Mechanical Engineering Technology	3	5
Engineering Management	1	6
Geospatial Engineering	1	0

Appendix B

TABLE B1: Summary of *t*-test and Cohen's *d* Results for Survey Questions for Each Class and Combined Data

Statement/Question	SP23 to FA23 Class 1 Comparison		SP23 to FA23 Class 2 Comparison		SP23 to FA23 Combined Comparison	
	<i>p</i> -value	Cohen's <i>d</i>	<i>p</i> -value	Cohen's <i>d</i>	<i>p</i> -value	Cohen's <i>d</i>
When I got stuck on a homework problem the zyBook/WileyPLUS helped me figure it out.	5.67e-9	0.85	4.45e-6	1.06	1.71e-11	0.9
When using the zyBook/WileyPLUS, I was usually able to understand the concepts being taught.	0.0039	0.38	0.0042	0.53	8.5e-4	0.42
The zyBook/WileyPLUS increased my confidence in understanding the course material.	0.0022	0.4	0.06	N/A	0.0019	0.38
The zyBook/WileyPLUS increased my confidence in solving engineering problems.	1.16e-5	0.61	0.019	0.43	1.28e-5	0.56
How often did you feel excited while using the zyBook/WileyPLUS?	0.016	0.31	0.024	0.39	0.0068	0.33
How often did you feel inspired while using the zyBook/WileyPLUS?	0.009	0.33	0.446	N/A	0.031	0.25
How often did you feel distressed while using the zyBook/WileyPLUS?	0.116	N/A	0.012	0.44	0.494	N/A
How often did you feel	0.212	N/A	0.0078	0.54	0.224	N/A

ashamed while using the zyBook/WileyPLUS?						
How often did you feel upset while using the zyBook/WileyPLUS?	0.242	N/A	0.0005	0.78	0.113	N/A
How often did you feel nervous while using the zyBook/WileyPLUS?	0.432	N/A	0.0023	0.62	0.068	N/A
How often did you feel frustrated while using the zyBook/WileyPLUS?	0.378	N/A	0.013	0.47	0.226	N/A
How often did you feel afraid while using the zyBook/WileyPLUS?	0.413	N/A	0.013	0.5	0.098	N/A