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An Interactive Web Native Textbook for Material and Energy Balances

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An interactive web native textbook for Material and Energy Balances

Abstract
Textbooks are experiencing a 21st century makeover. The utility of the textbook has diminished for the digital natives populating higher education today. The concept behind the Material and Energy Balances (MEB) zyBook® is to have students interact with the electronic book. While textbooks focus on the lowest levels of Bloom's taxonomy, namely remembering and understanding, engineers need the higher levels skills of applying and analyzing to earn an accredited undergraduate degree. The animations and question sets in the interactive, online format provide an excellent delivery of engineering course material. The zyBook format has been successful in other engineering disciplines and now has been translated to chemical engineering content. Data on the students' usage during the Spring 2016 semester as well as survey responses related to the new textbook format will be included in the talk.

Introduction

Lighting a room can be done using a number of different technologies. For many years, candles were the preferred method for lighting. In the late 19th century, Thomas Edison is credited with inventing the first incandescent light bulb that dominated use for about 100 years. More recently, more energy efficient technologies, such as fluorescent light bulbs, have displaced the older incandescent bulbs. Most recently, a Nobel prize was awarded for technologies related to LED light bulbs that are significantly more efficient than previous technologies.

Analogously, textbooks became a standard tool for higher education in the 20th century, and for many undergraduate engineering courses, remain as the standard method for information dissemination and reference. The engineering textbook is primarily used for defining terms and equations. Additionally, worked examples and homework problems are included in most engineering textbooks. However, the invention and mass production of the smartphone and simple access to factual information through Internet search engines, including Google, has changed how students obtain most of the information found in textbooks [1]. The price of textbooks has risen dramatically to more than $200 per traditional hard cover book used in an engineering course, and some student opt to use the Internet for free than add hundreds of dollars of books to their growing tuition costs.

The first steps of modernizing the textbook included electronic versions of paper textbooks. Searching the electronic documents, bookmarking, and highlighting are common for e-books read on smartphones and tablets in the early 2010s. Some supplemental tools, including online homework, have shown learning gains in students who learn using scaffolded problems with small penalties for incorrect answers [2]. While these tools are a clear extension of a paper textbook that instructors are comfortable with and used when they were students, fully interactive and low cost alternatives are starting to become available in engineering.

Comparing student learning across platforms and technology has evolved in recent years. Multimedia presentations led to improved test scores compared to students using text-based presentations [3]. Students have also shown preference to the diverse set of resources on the

Internet to a single, text-heavy textbook [1, 3]. More recently, interactive web-based content led to statistically significant learning gains compared to static web-based content [4, 5]. Interactive simulations and the tracking of mouse movements are also being well received by students and identifying misconceptions in students [6, 7].

In summary, active learning defines an entire class of techniques that continue to show in single studies and meta-analyses that students learn more through doing [8-10]. In this paper, the goal is to bring active learning to the students through an interactive textbook. The features of the book, data on student usage, and students' feedback will be detailed below.

Methods: A fully interactive textbook

An interactive textbook includes many of the standard features that digitally native students find in e-books and websites. No special software is need to view or interact with the zyBook, access is managed through any web browser. First, easy navigation through a table of contents and search engine help students quickly refer back to a certain keyword, indexed definition, or example. Data tabulated in appendices is also searchable, so scrolling through dozens of chemical names to find toluene is unnecessary by using the in-page search. The web-native book, or zyBook, is built on a responsive web template, so a clean, clear interface is available across desktops, laptops, and tablets; with most features also available on smartphone. Two specific features, namely learning questions and animations, will be detailed below with static, multi-panel figures in an attempt to capture the interactive nature of the book.

Several other unique features are available to the instructor and student. The instructor can arrange sections to be in the order that they teach the material and can omit sections that will not be covered. Students pay less than $50 to access to the zyBook for the semester and can re-subscribe for a small fee in future six month increments.

Placing homework questions at the end of a chapter to test students' comprehension of terms and new problem solving skills have been included in engineering textbooks for decades. More recently, quiz style questions with instant feedback on if the student is correct or incorrect have been added, usually at the end of the chapter also. In the zyBook, question sets are built inline with the text from learning questions. A learning question goes beyond having students identify a correct or incorrect answer. First, learning questions within question sets are scaffolded, so simple questions build into more difficult questions. Next, the feedback to students is both instantaneous and instructive. On the one hand, correct answers elaborate on why the answer was correct, which may include a few lines of detailed calculations. On the other hand, incorrect responses detail how and why the students could have come to the incorrect answer as well as information suggesting a path or information needed to identify the correct answer.

One example of a multiple choice question on the topic of reacting systems demonstrates the learning question format for material and energy balance students (Figure 1).

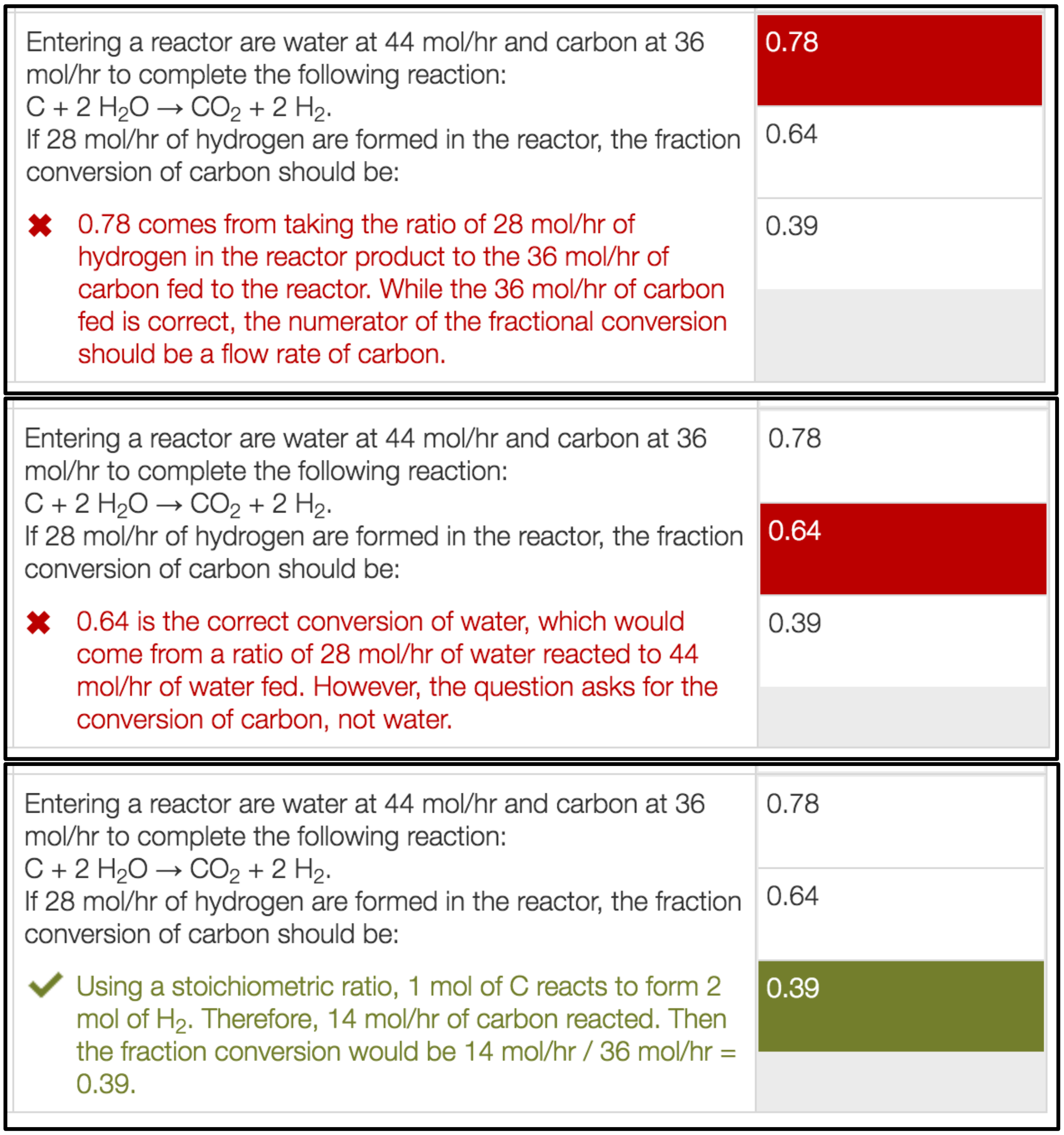
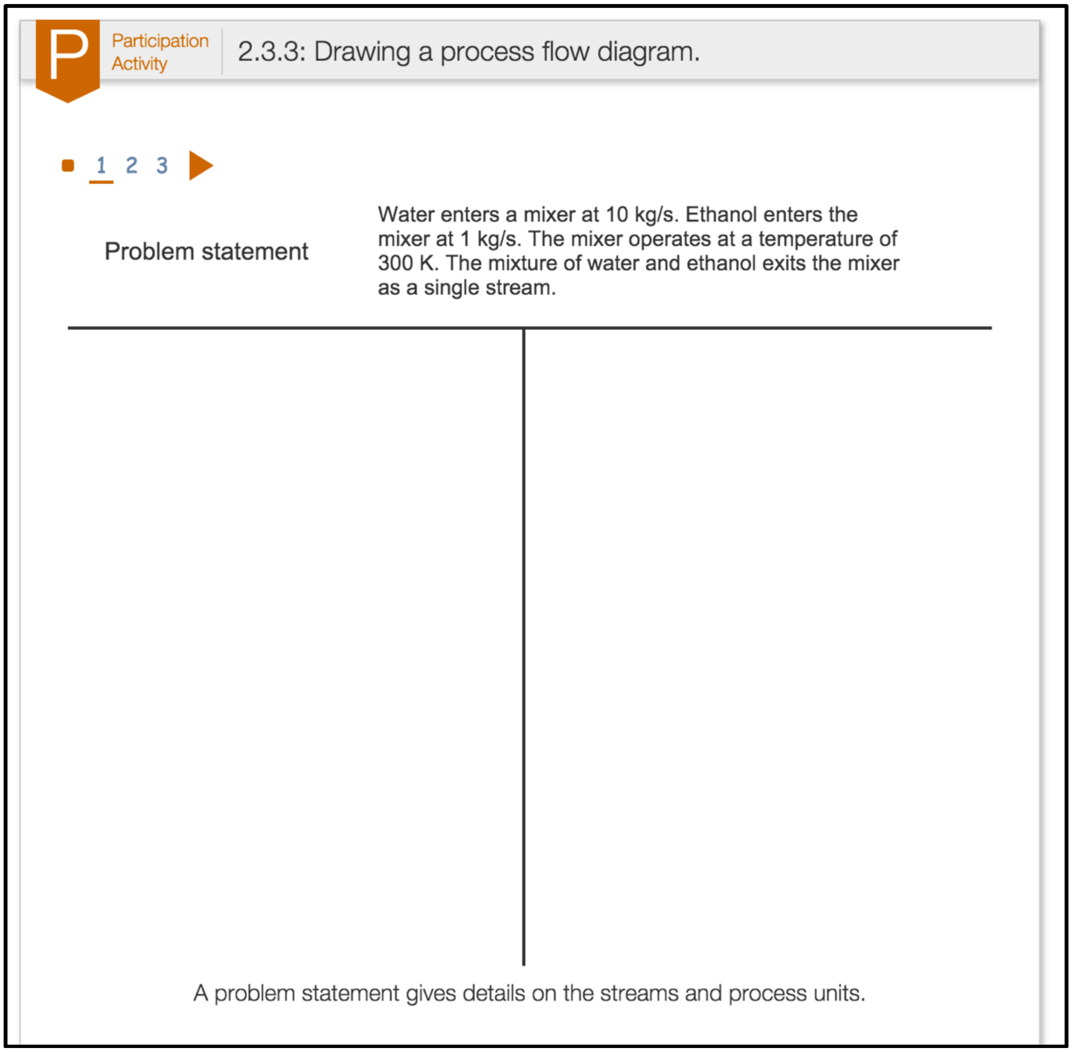


Figure 1. One multiple choice learning question related to reacting systems with all three answers selected. Each answer includes explanation on the correct or incorrect response.

Animations are another feature of a zyBook, which may be the first of its kind in a chemical engineering textbook. An animation takes a static image, such as a figure, and builds the text, equations, and diagrams through a small series of steps (usually 3 to 6 steps). The animations are interactive, as the students need to click to get the next step to appear, and each step includes a text explanation in addition to the action within the animation. Some examples of actions in animations include canceling terms in an equation, mathematical manipulations of equations, and simple actions occurring in process units, e.g., flow, separation, or mixing. The animations and question sets can be reset for students wanting an encore performance or as review before quizzes and exams.

An animation is hard to summarize in a static conference paper, but the multi-paneled figure below (Figure 2) provides one example of how new learning can occur through animations.

Faculty interested in seeing live animations can obtain a free copy of one or all chapters by visiting zyBooks.com directly and requesting an evaluation copy.



Participation Activity

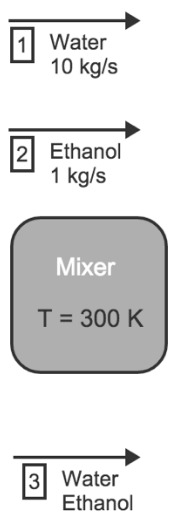
2.3.3: Drawing a process flow diagram.

1 2 3

Problem statement

Water enters a mixer at 10 kg/s. Ethanol enters the mixer at 1 kg/s. The mixer operates at a temperature of 300 K. The mixture of water and ethanol exits the mixer as a single stream.

Part of problem statement	Drawing
Water enters a mixer at 10 kg/s.	
Ethanol enters the mixer at 1 kg/s.	
The mixer operates at a temperature of 300 K.	
The mixture of water and ethanol exits the mixer as a single stream.	



Taking each sentence or segment and translating into streams and units is the next step. Stream numbers are added for each stream.

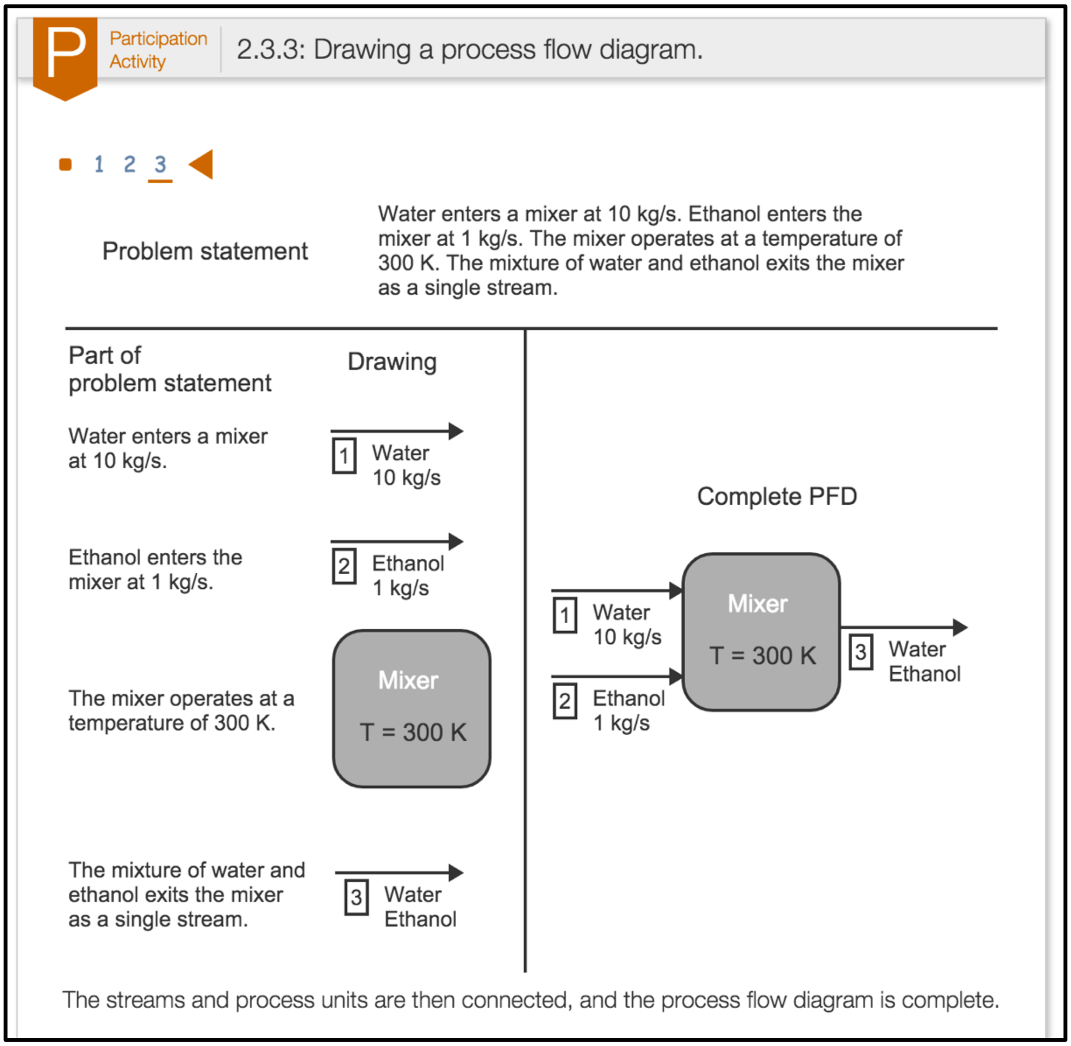


Figure 2. Three static images of a three step animation on drawing a process flow diagram.

Data and student response

The class to first use the Material and Energy Balances zyBook is at the University of Toledo during the Spring 2016 semester. The course consisted primarily of freshman students in their second semester of college. The enrollment included 105 students, about 59% male and 41% female students. The course met on Mondays, Wednesdays, and Fridays. Students are assigned to complete/participate in one or more sections of the zyBook before most classes. The number of sections to "read", or more correctly participate in, varied from 1 to 4 sections per class meeting.

Two types of student response indicate the students' willingness to adopt a new style of textbook. First, the participation grade is earned by each student when clicking the correct answer in a question set or for viewing each step in an animation. The participation grade is transparent, so the students can see their score accumulate as they read (similar to gamification of certain engineering courses [11, 12]). Clicking incorrect answers does not penalize the student, so students quickly come to appreciate the detailed feedback on why the incorrect answer is wrong, as well as additional information upon obtaining the correct answer.

The first set of participation results (Figure 3) show a small learning curve in understanding the participation grade. For Chapter 1, nine sections were assigned over the course of one week. Initially, about 60% of the class registered, obtained a copy of the zyBook, and earned 100% participation in the first reading assignment (Sections 1.1 and 1.2). With 10% of the class partially participating in Section 1.1 and 1.2, the adoption of the zyBook met the instructors' expectations for a freshman course. However, the number of students who did not participate in the reading jumped from 36 to 48 with the second reading assignment. The data in Figure 3 was shown to the students during each class early in the semester (as reading assignments are due at 8am preceding the 11am class time). After the second assignment where fewer students participated, the instructors reiterated the syllabus, which included 5% of the total course grade being awarded for participating in the zyBook. Next, the participation jumped to nearly the whole class with ninety students completely finishing Sections 1.7 to 1.9, eleven students partially completing the assignment, and only 4 students not completing the reading. Overall, data from the entire semester will be included in the talk.

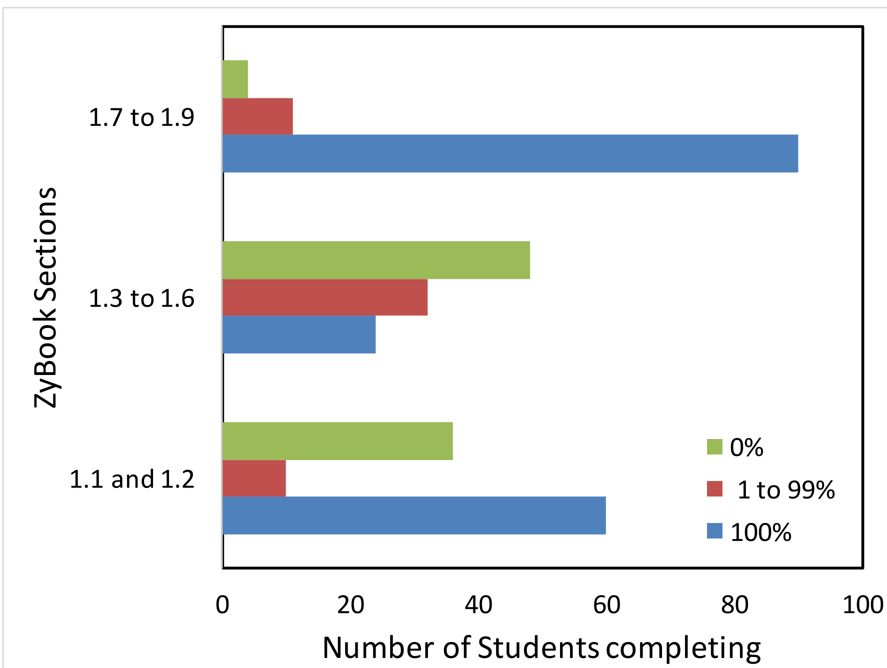


Figure 3. Sections of the zyBook assigned for reading as a function of the number of students completing, partially completing, or not completing the reading.

The second type of student response was obtained through informal, anonymous feedback after completing the Chapter 1 reading. On index cards, the students responded to three course related questions. Only the first question is pertinent to this study; the question stated: List two things you like about the zyBook. Early in the semester during a Material and Energy Balances course, putting a positive spin on most questions has proved successful in encouraging fragile students who are learning to think like an engineer for the first time. The top four responses garnered at least 10 students' votes (Table 1). The interactivity, and specifically the animations, resonate with the digitally native students. The learning question model was also lauded as constructive feedback is lacking in most textbooks and learning materials. Finally, the lack of large chucks of text to read is preferred by the students.

Table 1. Features that students like about the zyBook.

Top responses to "two things you like about the zyBook"
Animations
Interactive
Explains why an answer is wrong
Concise/Less text

Three students' comments reiterate the class's consensus from the table above: 1. "I like that it is short, sweet, and to the point. There isn't pointless information.", 2. "Its interactive. You aren't just reading paragraph upon paragraph. It goes by much faster yet I retain more information.", and 3. "Interaction - keeps me in interested in learning. Checks completion – forces me to read when otherwise I probably would not.".

Conclusion

In summary, a web native and interactive textbook has been written and implemented in a Material and Energy Balances course. Several unique features distinguish the zyBook from traditional textbooks. First, question sets with learning questions are scaffolded from easier to more difficult as well as explain why each answer is correct or incorrect. Animations turn figures into interactive constructions of new concepts (e.g., phase diagrams), operating principals of common equipment (e.g., a distillation column), and developing useful equations (e.g., the energy balance for a steady state system with negligible kinetic and potential energy). Finally, students receive feedback in real time as they read/participate in each section. Feedback is also provided to the instructor to verify that the reading was not completed, partially completed, or fully completed.

Disclaimer

The author may receive royalties from sales of the zyBook detailed in this paper.

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