Integrating a Digital Textbook into a Statics Course

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***Abstract*—This innovative practice work-in-progress paper presents the findings of the first implementation of a digital textbook developed by the authors. Recognizing that technology offers new ways to conceive of what a textbook is and does, the digital statics textbook is designed to be a personalized learning experience for students. It includes numerous innovations to provide real-world context and motivation for the theory, scaffold learning, support students in developing systematic and structured problem solving processes, and provide immediate feedback. The online materials were integrated into a lecture- and lab-based, active-learning course offered for approximately 80 students in a 10-week quarter. The online resources were accessible to the students through the university's learning management system. While students learned the material and performed well, they were challenged by this new method of accessing a textbook and identified several limitations of the integration of the digital resource in the course. Instructors need to determine the right mix of online problem solving with immediate feedback and paper-based homework that reinforces a structured problem solving approach. A second offering was underway at the time of writing this paper.**

Keywords—online education, digital textbook, statics

I. INTRODUCTION

Digital technologies hold great promise for enhancing teaching and learning, and engineering education is no exception. Digital textbooks are available for subjects such as engineering mechanics [1], circuit design [2], and chemistry [3]. The evolution of textbooks is in part motivated by the educational promise of digital technology in addition to a changing textbook-market reality (where, for example, some students choose to lease their textbooks and others choose to go without). Students can access full courses offered at a distance through such organizations as Coursera and the Open Learning Initiative [4], and through individual instructor efforts. Furthermore, learning management systems (LMSs), which allow for easy-access of course materials (e.g., assignments, syllabi, lecture notes) and facilitate course administration (e.g., distributing quizzes, making announcements, recording grades), have become ubiquitous in supporting engineering courses. LMSs also enable the instructor to point students to curated lists of digital course-related resources (e.g., Khan Academy modules on linear algebra). That is not all; Felder & Brent's Teaching & Learning STEM: A Practical Guide [5] lists additional digital technologies that are making their way into engineering education, including personal response systems, simulations and virtual labs, and interactive multimedia tutorials.

This paper considers the incorporation of a new digital textbook [6] into a standard statics course. This textbook offers a variety of resources beyond a conventional mechanics textbook, thus creativity was needed to integrate scaffolding and pointers into the course so as to not overwhelm students, and further, to help them effectively navigate the digital resource as a useful and important study aid. Assessment of this integration in the first course offering is discussed along with changes being incorporated into a second offering.

II. DIGITAL TEXTBOOK INNOVATIONS

The full digital textbook, *Engineering Mechanics: Statics* is available within the WileyPLUS platform; however, a loose-leaf version of the content (without the exercise problems) is also available for purchase. The textbook was developed to be a personalized experience for students who are grappling with the material for the first time. The writing style is intended to help the students feel that they are in conversation with the authors. Without skimping on rigor, the goal is for the material to be accessible to students with many backgrounds and interests as well as fun to learn. Several innovations to achieve this goal are:

- *Learning roadmaps and summaries*: Every text section and exercise is associated with learning objectives so that instructors and students understand what students are expected to learn. Each chapter culminates with a "Just the Facts" section that summarizes concepts and equations.
- *Scaffolded learning*: Each section starts with a short "Watch-It" video to demonstrate application of the theory and motivate the study of a particular statics concept. For example, a video shows a child riding a bicycle and then reviews how to create a free-body diagram of the rear wheel in the chapter on free-body diagrams. Another describes designing for traffic on truss bridges to motivate learning the method of joints in the chapter on member loads in trusses. Students scaffold their conceptual understanding by performing interactive "Are-You-Ready" exercises that provide them with feedback on their mastery of the skills they need to be successful in that chapter. Then they have the option of completing targeted short "Do-It" exercises to master individual concepts. Selected practice problems provide hints, partial solutions, and guided problem solving to help students gain

competency and confidence before they tackle complex problems from start-to-finish.

- *Real-world connections*: Examples and exercises ranging from bicycles, climbing equipment and spacecraft, to kitchen utensils, electronics and the human body are designed to connect statics to students' everyday lives and to engineering practice. These connections are reinforced in the "Watch-It" videos.

- *Focus on modeling*: The digital textbook devotes an entire chapter to modeling with free-body diagrams. To help students master this perennially challenging topic, they are given a structured four-step process for developing a free-body diagram. Students can use an interactive tool to build and receive immediate feedback on free-body diagrams.

FOUR STEPS TO CREATING A FREE-BODY DIAGRAM

1	Study the physical situation
2	Draw system; state assumptions
3	Draw known loads
4	Identify and draw support loads

- *Structured problem solving*: A structured three-phase process consisting of understanding the problem, modeling, and confirming values is used for all examples and exercise solutions. Phases are broken into smaller steps such as listing goals, given parameters and modeling assumptions, drawing the model, formulating and solving equations, then checking results and summarizing how goals were met (Fig. 1).

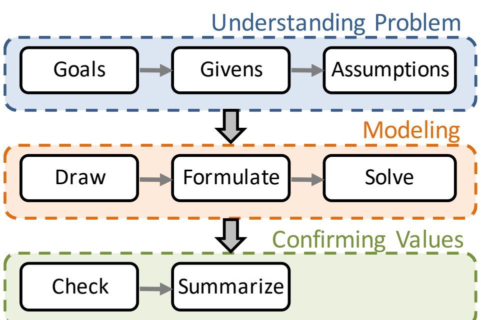

Fig. 1. Example of the structured problem solving process followed.

- *Timely feedback*: It is well known that students benefit from timely feedback on their assignments, but the budget-driven constraints of increased class sizes and fewer teaching assistants and graders can make this difficult. The digital textbook is designed to give students rapid feedback on their solutions, while at the same time the instructor can control the amount of access students have to hints and solutions. The instructor receives ongoing feedback about how the class is doing, allowing her to focus in-class instruction where it is most needed.

III. Digital Textbook Implementation

In fall quarter 2017, the digital textbook was integrated for the first time into *Introduction to Solid Mechanics*, a 10-week sophomore-level course with the following learning objectives.

(1) Apply analytical skills to evaluate structural response of systems in static equilibrium,

(2) Explain and demonstrate the role that equilibrium analysis and modeling play in engineering design and engineering applications more generally, and

(3) Communicate about structural systems using mathematical, verbal and visual means.

Taken as a whole, these objectives are consistent with ABET Criteria 3 in helping students acquire the abilities to solve complex problems (Criterion 3.1) and communicate with a range of audiences (Criterion 3.3).

Specifically, the course included the concepts of force and moment equilibrium and free-body diagrams, and their application in analysis of systems. In implementing the reconceived textbook in the course, the authors built on strategies presented in *How Learning Works* [7], recognizing students' need for (a) timely feedback, which is more easily achieved online than with paper-based assignments, and (b) connecting the learning objectives to the "real world" as well as students' own experiences as an element of motivation. Equally important was the need to practice the structured problem solving approach, which is best done on paper. Students completed six homework assignments (problem sets), two team-based projects, a midterm and a final exam. In-class participation comprised collaborative problem solving and lab assignments, and occasional one-minute paper reflections that complemented formal lectures held two times per week (Tuesdays and Thursdays) where key course topics were introduced. In class, the students were grouped in four "pods" of roughly 20 students; each pod had a designated course assistant and a designated seating location in the classroom that rotated weekly. In addition, eight hours of office hours and a voluntary problem-solving session were held each week.

The digital text, which students accessed through the Canvas LMS, was formally integrated into the first three homework assignments (through week 4), and through assigned readings in the rest of the course. Each of the first three assignments was assigned on a Thursday and was made up of two parts.

Part One was online, utilized the digital assets of the textbook bundled together as an assignment, and was due on Monday at noon. It was designed to help students engage with immediate feedback on the basic concepts and served as a preparation/warm-up for the second part of the homework. Individual student and overall class performance on Part One was also immediately available to the course instructor, so that the Tuesday lecture could be modified accordingly to focus on concepts students were finding challenging. Table 1 describes HW1 Part One to illustrate how the instructor curated, bundled and organized a subset of the elements of the digital textbook into a homework assignment. Students were logged into Canvas for 20 to 120 minutes in completing HW1 Part One.

Part Two was paper-based and emphasized students solving more complex analysis problems along with presenting their work using a formal engineering analysis process. Part Two was designed to take students 4 to 5 hours to complete. It was due on Thursday at the beginning of class; graded work was returned to students the following Tuesday at the end of the class session.

TABLE I. COMPONENTS OF HW1-PART ONE (THE ONLINE PORTION)

Component	Description
Are you ready?	These seven problems, some with multiple parts, were to be review material, covering prerequisite concepts on the right-hand rule, basic trigonometry, appropriate number of significant figures, and vector basics.
Do It	These five multiple-choice problems focused on the mathematical concepts of force (e.g., writing the unit vector for a given force, determining the magnitude of a force, and identifying planar and nonplanar forces). Some problems included “hints” and all problems linked to the relevant text.
Open-Ended Problem #1	This problem asked students to define what engineering modeling is, and why engineers create models. It was based on reading text Section 1.1, and as such was designed to connect text and homework.
Open-Ended Problem #2	This problem asked students to view three of the Watch-It videos (2.1-Why Do We Care About Forces?; 2.5-Representing Forces Mathematically; and 2.6-Force Vector Addition) to identity which were most effective in helping their learning, and which had concepts that were still “foggy” in their mind. It was designed to connect the video elements of the digital text to homework.

Fig. 2 is taken from the instructor display of HW1 Part One results. The 12 percent “no attempt” represents the teaching team who are listed as enrolled in the course but did not complete the assignment. The instructor was able to see that students were challenged by Are You Ready 3.01 and 3.02, and Do It 2.5.1m, and thus these problems became part of class review following the assignment’s completion. The last two problems in Fig. 1 needed to be graded by hand, so the scores do not appear. Patterns of challenging problems were similar in early assignments in the second offering of the course. These identified challenges are being used to shape lecture material covered in the future course offerings.

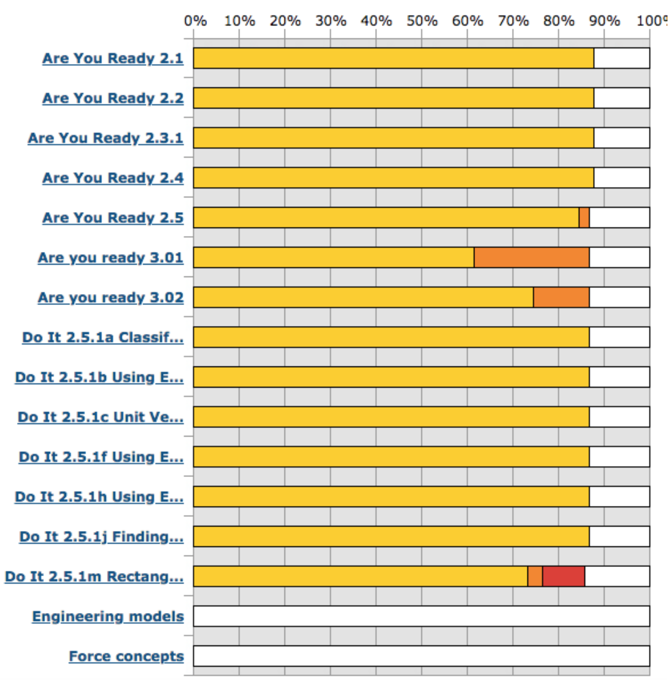

Fig. 2 Class performance on HW1 Part One, yellow (full credit), orange (partial credit), red (attempted - no credit), white (did not attempt).

This initial offering of Statics with the digital textbook was a first trial at the integration process. Based on lessons learned, as outlined in the next section, we will be able to improve its integration into the course as well as be in a position to begin experimenting with different means of integration and how that affects student learning (in other words, to start some more formal experimentation).

IV. RESULTS

We are happy to report that the end-of-course evaluation indicated that students felt the three course learning objectives were achieved, with over 90 percent reporting that each was very or extremely well achieved (so happily our students believed they learned to apply mechanics!). Problem sets were highly valued, with 83 percent expressing that this course element was very or extremely useful in their learning.

On the same evaluation, the role of the digital textbook in supporting this learning is less clear, as only 34 percent of the students expressed that this course element was very or extremely useful in their learning (and over a 1/3 reported that it was only slightly or not at all useful). We concluded that we have a lot to learn about how to effectively integrate a digital textbook into a course.

A. Challenges

We can gain more insights into the student experience as affected by the digital textbook by reviewing the open-ended survey responses, and by the student focus group that we ran several weeks after the course finished. The teaching team also contributed their own “lived” observations. Combined, these data-sources allow us to identify five challenges:

1. The unfamiliar titles of some modules and resources as well as the organization of the modules and resources within the LMS caused confusion for some students. As a result, some students were not able to make maximum use of the digital textbook. For example, they thought they were limited to accessing only textbook sections linked from the homework assignments, when in fact they had access to the entire text and all of its resources. *Despite being digital natives, students need an orientation to how to use this new type of learning resource.* Interestingly, Van Horne et al. [8] found higher satisfaction with a digital textbook when students first viewed a video on how to effectively use its interactive resources, although use of those resources did not increase.

2. Navigating a text where they could not “turn pages,” mark in the margins or apply sticky notes (though new digital tools are helping address these latter two difficulties) was cumbersome for some users (both students and the teaching team). Users could only have one-window of the textbook open at a time, which made moving between problems, videos and text awkward. Consistent with several studies [3, 9], some students indicated they are still more comfortable with, and therefore prefer, paper resources.

3. Grading open-ended online portions of the homework was labor intensive, and less “real time” than the automatically-graded portions of online assignments. Grading the paper-based portion of the homework remained labor intensive.

(Yet, we note that students indicate that the problem sets are one of the most powerful parts of their learning experience.)

4. The workload for the course was felt by some students to be too great. Students indicated that they spent more time outside of class reviewing the digital course materials than they would with a paper-based text, and/or spent more time on homework assignments (perhaps due to having both online and paper-based parts). It appears we did not achieve a good time-balance between the digital and paper-based parts of the homework assignments (prior course offerings used only paper-based homework assignments).
5. The digital textbook was used in an integrated fashion only in the first four weeks of the course. Students wanted to use it more given that they were required to purchase it.

B. Next Steps

Our immediate next steps involve continuing to integrate digital tools into the course. In the second offering, we have created explicit pointers to digital resources in, for example, the first two weeks of lectures, in the paper-based part of the homework, and in all lecture handouts. This integration is in service of improving the "user experience." In addition, the two-part homework is being implemented in six out of seven homework assignments throughout the quarter with reductions in paper-based problems to keep outside classwork to 5-6 hours total per week for the 3-unit course. The students are asked to complete the online portions every Monday followed by turning in paper-based solutions the following Thursday. We see these steps as progress toward addressing challenges 1, 4, and 5.

With these changes implemented in the second offering we have found through a mid-course survey that 57% of the class found the online assignments "Helpful" or "Very Helpful" for learning the course material prior to the midterm with an additional 39% finding it "Somewhat helpful." For written homework, 96% of the students found it "Helpful" or "Very Helpful" for their learning. On the otherhand, student feedback reported that the number of assignments and deadlines throughout the course felt too high for a 3-unit course workload.

With regard to challenge 3, Gradscope, which allows for online grading of conventional paper-based assignments (as well as any opened-ended problems in the online portion), is being considered to speed-up providing feedback to students (without reducing the quality).

Other improvements for the future that could enhance the integration of the digital textbook into the student's learning experience are, for example, to:

- create explicit "help pointers" to digital resources in project and lab descriptions, so that students could more effectively reference these resources as help beyond in-person office hours (which they find highly useful in the course),
- set-up a modified "flipped classroom," where sections of the digital text could be assigned to students before each Tuesday and Thursday class period, then a shorter amount of class time would be used for lecturing and more time could be devoted to in-class, coached problem solving.

Addressing challenges 1, 2, and 4 will continue to take more work. Responding to these challenges requires a deeper understanding of the student learning experience to identify optimum organizational and delivery strategies (recognizing that there is no single optimum process for all learners!) Being more mindful of student time is part of this. We need to gather more information about how students combine course components and fit them into their learning process, along with their own personal background, interests and preparation to advance their learning. In other words, *How do students integrate, for example, reading, watching videos, practicing concepts, and listening in class, with doing the modeling and analysis themselves?* Having a variety of resources available lets students with different learning needs and approaches find the combination that is right for them. At the same time, as new tools are introduced we should help them think through how to most effectively use those tools. We also need to remember not to "overstuff" the resources we give them (sometimes too much is just that….too much!).

V. CONCLUSIONS

New resources involving new digital technologies will continue to be created, and they have the potential to add to learning. At the same time, in order to be effective, they need to be carefully integrated into course design and delivery. The sophomore-level statics course described in this paper serves as a case in point. While students learned the material and performed well, they were challenged by this new way of accessing a textbook. Even as "digital natives" they need an orientation to the tools and strategies for using them most effectively. Students identified several limitations with the integration of the digital resource in the course. Faculty need to think carefully about the design of the modules in the LMS. The student experience is a reminder that instructors need to determine the right mix of online problem solving with immediate feedback and paper-based homework that reinforces a structured problem solving approach. Our next steps are to continue to refine how this new digital resource is integrated into our course, and to define more formal experiments where we can study, for example, how the balance between online vs. paper homework affects different students' learning.

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