A CASE STUDY OF STUDENT AND INSTRUCTOR REACTIONS TO A CALCULUS E-BOOK

MARTINA BODE, MEHDI KHORAMI, AND DANIEL VISSCHER

Abstract. This article details the results of testing an e-book in two differential calculus classes. While we, as math instructors, are drawn to the components of the e-book that promote conceptual understanding—such as the interactive figures—the students reported liking the assessment support most. We find that students were initially excited about the interactive figures, but the majority did not use them much over the term. The students who did make use of the interactive figures, however, also reported that the figures improved their understanding of calculus concepts.

1. Introduction

Over the past couple of years, electronic books, or e-books, have become increasingly popular in the education world. Along with publishers becoming more technologically savvy, the number of students who own smartphones, laptops, Kindles, tablets, and other electronic devices is growing. It is not at all uncommon, for example, to see students reading books on Kindles, tablets, or other electronic devices. Drawing on these observations, the following questions motivate this study: Will we, as math instructors, see instructional benefits of using e-books instead of physical textbooks in our courses? Can e-books enhance students' learning in mathematics? Are e-books the resources of the future in mathematics education?

A number of studies conducted over the past decade address the use of e-books in academia. The majority of these studies concern the logistical and ease-of-use pros and cons of using e-books, rather than physical texts, in a general academic setting. On one hand, e-books cost less, are more portable, are more convenient, weigh less, and students consider them more up-to-date. On the other hand, the electronic text is harder to read, harder to annotate, and can be difficult to navigate and browse on a screen ([1],[2],[3],[7],[8],[11]). Reports on the use of e-books in academia, as well as an overview of some campus e-book initiatives, can be found in the research bulletins [5] and [6]. While the cost of textbooks is a motivating factor for many e-textbook initiatives, Rickman et. al. suggest that the future success of e-books in academia is more likely to hinge on the successful integration of enhanced learning resources, such as interactive figures, that are much easier to incorporate in the e-book format ([7]). This (potential) aspect of e-books has particular promise in mathematics, where visualization plays an important role in understanding concepts and developing intuition. Indeed, the incorporation of interactive figures was a key factor in our decision to class-test a calculus e-book.

Key words and phrases. calculus, e-books, interactive figures, technology.

Related to the question of how students would use a math e-book is research on how students use (physical) math textbooks. This is an open research area, as described by Selden and Shepherd [9] in a 2013 report: "it seems to us that crucially missing is substantial research on how students actually read, and use, their mathematics textbooks, in particular, on what parts of their mathematics textbooks they read, and why." There are a few studies in this direction. In [4], Lithner describes an "Identification of Similarities" strategy students use when working through calculus exercises in textbooks, searching for completed examples that closely resemble the problem they are trying to solve. Similarly, Shepherd, Selden, and Selden [10] find that proficient readers (who are also good at math, as determined by ACT scores) are not effective readers of their math textbooks (as determined by the ability to do a straightforward task after reading). Likewise, Weinberg, Wiesner, Benesh, and Boester [12] report that students tend to build their mathematical understanding by looking at worked examples, rather than reading the expository text (where authors try to develop conceptual understanding). However, they also find that students do use their textbook more productively when they believe they are asked to do so by their instructor.

This paper reports a preliminary study about whether and how students use a calculus e-textbook, as well as our experience as instructors with using the e-textbook. It concerns an e-book that we tested in two differential calculus classes during the winter quarter of 2012. The e-book we used has a wide variety of interactive figures that are integrated into the text, a distinctive feature among the e-books we considered and one which we envisioned would enhance our students' learning and conceptual understanding of differential calculus. Furthermore, we were excited about how these interactive figures could enrich our classroom instruction, given that our classrooms are equipped with smart equipment and laptop hookups. We were interested in what our students would think of and how they would use the e-book, and we conducted a study consisting of two surveys and a middle–of–the–term focus group. We predicted that the interactive figures would be a valuable tool for students that was unique to the e-book version of the textbook, and thus, they would be the features of the e-book that students would like the best. Our research, however, tells a slightly different story. The data that we collected from students indicates:

- Students were initially enthusiastic about using an e-book and its interactive figures, but in practice very few students took advantage of the interactive figures as a means of enhancing and extending their personal study.
- The students who did make use of the interactive figures also reported gains in their learning and conceptual understanding from them.
- Among our students, the most popular feature of the e-book was the homework helper, a component of an online homework system that was paired with the e-book.

Our vision was that students would take advantage of interactive figures and other learning tools available in the e-book. However, this contrasted with how most students actually used it—to access homework helpers that are readily available in many other online homework systems used in connection with physical textbooks. Their use of the e-book for homework help does not surprise us, though. Our previous experiences as calculus instructors are that our students like to watch

tutorials about how to work out specific homework problems and get step-by-step guidance on how to solve similar problems. In other words, students are strategic when they are doing their homework, and they like having ready access to help when they need it to complete assignments.

While most students did not realize our vision for implementing the e-book, a small number of students did. These students reported both using the interactive figures and gaining understanding from them. Moreover, some students informally remarked on how helpful the interactive figures were in classroom instruction. Based on our data and personal experiences, we believe that the interactive figures hold promise as a learning tool for improving conceptual understanding of calculus. Like any learning format that is new to students, however, it will require explicit instruction, support, and time for students to learn how to use it effectively.

2. Methods and Data

The primary objective of this preliminary study was to record trends in students' use of and thoughts concerning the e-book—the course textbook that was used in two sections of differential calculus during the winter qurater of 2012. These sections comprised a trailer sequence, a sequence in which we expect about 60% of the students to have taken calculus before (compare with about 80% in the main sequence). We also expect to see many students who are attempting the course for the second time (i.e. they started in the fall but dropped it): about 30–50% of the students fit this category. One of the authors not involved in the instruction of either section of the course administered written surveys at the beginning and at the end of the quarter, as well as conducted an in-class focus group around the middle of the quarter. Of the 45 students enrolled across both sections of the course at the beginning of the quarter, 42 completed the initial survey, 38 participated in the focus group, and 34 submitted the final survey. The majority of students reported economics, engineering, pre-med, or science as their major, although there were also a number of education, humanities, journalism, and social policy majors. None of the students were majoring in mathematics. Few of the students had used an e-book before. On the final survey, 27 of 34 students claimed that they had no previous experience with e-books, while 5 had used an e-book in a class setting before, and 2 for personal use. Our survey questions focused on how students viewed the e-book and its interactive features at the beginning of the quarter and whether or not their perceptions changed over the duration of the course.

In this section, we present data from the two surveys, sorted by questions regarding overall experience, amount of use, interactive figures, and whether or not students recommend using this technology again, as well as data from the mid-term focus group. The first group of questions relate to students' overall experience or general impressions of the e-book and its specific components. Question 1 appeared on the initial survey (I), while the rest are taken from the final survey (F). For each question, students selected from five boxes, ranging from "very negative" on the left to "very positive" on the right. The boxes for the last question ("Did you find the study devices on [the online assessment tool (OAT)] helpful?") ranged from "not helpful/did not use" on the left to "very helpful" on the right. All of the response numbers given in the following tables are recorded as percentages, in order to make them comparable.

(1) What is your initial reaction to the e-book?
(2) How was your overall experience with the e-book and supporting materials?
(3) How was your overall experience with the e-book (text and figures)?
(4) How was your experience with [the online assessment tool (OAT)]?
(5) Did you find the study devices (study problems, similar problems, view an example, etc.) on [the OAT] helpful?

		very neg.				very pos.
Question	**Avg.**	**1**	**2**	**3**	**4**	**5**
1. Initial reaction (I)	3.50	0%	7%	43%	43%	7%
2. Overall experience (F)	3.32	3%	9%	47%	35%	6%
3. Text and figures (F)	3.09	6%	21%	38%	29%	6%
4. OAT (F)	3.74	0%	6%	35%	38%	21%
5. Study devices (F)	4.44	0%	6%	3%	32%	59%

TABLE 1. Students' impressions of the e-book and its components.

The responses to the first question indicate that about one half of the students reacted positively to the e-book at the beginning of the quarter. Responses to Question 2 show this trend paled somewhat by the end of the quarter, although the students' opinions of the e-book were still more positive than negative. While experiences with the electronic text and its interactive figures are split evently, responses to Question 2 are elevated by very positive reactions to the online assessment tool and especially to its associated study devices.

The second group of questions focuses on students' reported use of the e-book, compared to their perceptions of how they would have used a physical textbook. The first question was posed on the initial survey (I) and the second on the final survey (F).

(1) Compared to a physical textbook, how much do you plan to read the e-book (on a computer)?
(2) Compared to a physical textbook, how much did you use the e-book (the actual text and figures, not [the OAT] problems)?

		much less				much more
Question	**Avg.**	**1**	**2**	**3**	**4**	**5**
1. Plan to read (I)	3.02	7%	21%	40%	24%	7%
2. Actual use (F)	2.21	24%	41%	26%	9%	0%

TABLE 2. Students' reported use of the e-book versus a physical textbook.

While students' initial responses indicate that class-wide use of the e-book would be on par with that of a physical textbook, the final survey shows that in practice students used the e-book much less than they imagined they would have used a physical textbook. In addition to how much students used the e-book, we also note *how* they used it. Of the 42 students who responded to the initial survey, all 42 planned to access the e-book on a portable laptop, 11 planned to use university computer labs, and 16 planned to print at least some sections of the e-book. Of

the 34 students who responded to the final survey, all 34 reported using the e-book on a portable laptop, 6 students additionally accessed the e-book on university computers, 1 reported printing sections of the e-book, and 1 bought a physical copy of the textbook.

The third group of questions concerns student reactions to the e-book's interactive figures. Again, the first question appeared on the initial survey (I), while the other two were part of the final survey (F).

(1) Do you think the interactive figures will help you study?
(2) How much did the interactive figures affect your understanding of calculus concepts?
(3) How much did you use the interactive figures?

		not at all				a lot
Question	**Avg.**	**1**	**2**	**3**	**4**	**5**
1. Help study (I)	3.93	0%	2%	19%	62%	17%
2. Affect understanding (F)	2.79	6%	39%	33%	12%	9%
3. Amount of use (F)	2.50	12%	50%	21%	12%	6%

TABLE 3. Students' reported use and perceptions of the interactive figures.

While students initially felt that the interactive figures would help them study and learn calculus concepts, they used the figures less and the figures helped them less than they imagined. One question that this raises is whether responses to these last two questions are correlated—that is, are the students who report using interactive figures more also the ones who report gaining more from them? We find a positive correlation between these two sets of data—the correlation coefficient between responses to these two questions is $r = 0.60$—and the linear regression on this data is shown in Figure 1. Note that because the interactive figures were also used during class sessions, students may have reported using the figures infrequently, yet still gaining some understanding from them.

In the middle of the quarter, we conducted a focus group during which we asked students to provide feedback on aspects of the e-book that were enhancing their learning in the course. Students were split into small groups and asked to respond to three prompts about the effect of the e-book on their learning. After a moderator solicited ideas from the class, students agreed on consensus answers. Then, they individually rated how strongly they agreed or disagreed with the consensus answers. Students reported agreement on a scale from 1 to 9, with 1 indicating strong disagreement and 9 indicating strong agreement. In response to the prompt "The following aspects of the e-book enhance my learning," students in both sections of the course determined interactive figures and examples displayed in the homework (a reference to the study devices on the OAT) to be consensus answers. Individual agreement data, shown in Table 4, indicates that students in both sections felt that the examples displayed in the homework enhanced their learning more than the e-book's interactive figures.

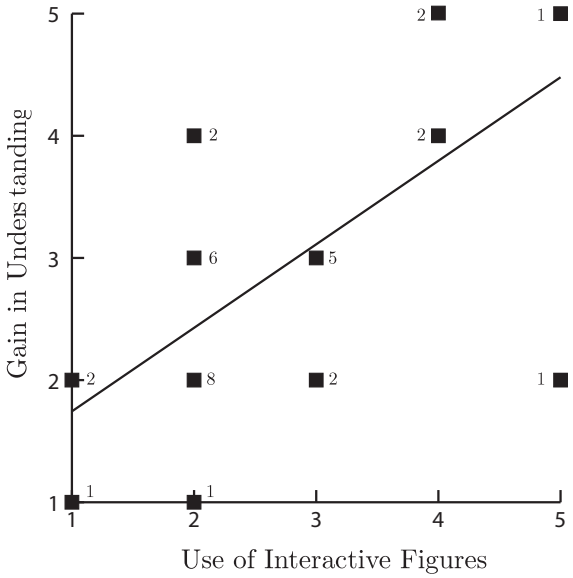

FIGURE 1. Linear regression of students' reported gain in understanding versus their use of interactive figures. Note that the interactive figures were used in class, so students might report gain in understanding from the figures without reporting much use of them.

	Class 1		**Class 2**	
	interactive figures	examples on HW	interactive graphs	examples displayed in the HW
Average	4.75	7.50	5.86	7.68
disagree (1–3)	4	0	3	0
neutral (4–6)	10	4	8	5
agree (7–9)	2	12	10	17

TABLE 4. Individually indicated agreement with class consensus answers to the prompt "The following aspect of the e-book enhance my learning," reported in numbers of students. (Note that one student in Class 2 abstained from voting on the "interactive graphs" consensus answer.)

The last group of questions, both given at the end of the quarter, attempts to sort out students' impressions of an e-book as a general format for a calculus textbook versus their experience with this particular e-book.

(1) If your friend were taking a calculus course next term, would you recommend they enroll in a section using *an* e-book?
(2) If your friend were taking a calculus course next term, would you recommend they enroll in a section using *this* e-book?

		not at all				definitely
Question	**Avg.**	**1**	**2**	**3**	**4**	**5**
1. Recom. *an* eBook (F)	3.12	3%	21%	50%	15%	12%
2. Recom. *this* eBook (F)	3.44	0%	9%	47%	35%	9%

TABLE 5. Student responses to recommending a generic calculus e-book versus the particular e-book used in this study.

Student responses are almost evenly split for recommending a generic e-book, while they are markedly more positive for recommending the particular e-book used in this study.

Additionally, we collected data on which section students were enrolled for 42 of the 44 total students who contributed to this study. Of these 42 students, 28 students indicated they were in Section A and 14 students indicated they were in Section B. Table 6 displays the average response scores by section.

Question	**Avg.**	Sect. A	Sect. B
1.1. Initial reaction (I)	3.50	3.57	3.36
1.2. Overall experience (F)	3.32	3.36	3.09
1.3. Text and figures (F)	3.09	3.23	2.64
1.4. OAT (F)	3.74	3.64	3.91
1.5. Study devices (F)	4.44	4.32	4.64
2.1. Plan to read (I)	3.02	3.29	2.50
2.2. Actual use (F)	2.21	2.45	1.64
3.1. Help study (I)	3.93	4.04	3.71
3.2. Affect understanding (F)	2.79	3.05	2.18
3.3. Amount of use (F)	2.50	2.73	1.91
5.1. Recom. *an* eBook (F)	3.12	3.27	2.64
5.2. Recom. *this* eBook (F)	3.44	3.50	3.27

TABLE 6. Students' opinions and use of the e-book sorted by section.

Sections A and B had different instructors who diverged slightly in style during the semester, but they began class using the same syllabus and provided the same introduction to the e-book. The instructor for Section A used a document camera while lecturing and incorporated the interactive figures into lectures. The instructor for Section B used the blackboard while lecturing and rarely used the interactive figures during instruction. The instructor for Section A also explicitly encouraged students to use the interactive figures while studying on their own.

3. Discussion

We draw the following conclusions from our data on students' reactions to the e-book.

In general, students were initially enthusiastic about using an e-book and its interactive figures, but in practice very few students took advantage of the interactive figures as a means of enhancing and extending their personal study. Students'

initial reactions to the interactive figures were positive, and they suggest that the students felt optimistic that the interactive figures would help them learn and build conceptual understanding. Likewise, in the middle of the quarter, the students reported in focus groups that the interactive figures were enhancing their learning; although, there was individual disagreement with this statement and, on average, responses were neutral. By the end of the quarter, students' use of the interactive figures and their positive impressions of them had substantially declined. We see this trend as a result of students becoming increasingly grade–driven over the course of the term. While students began the term focused on the course materials and the ways in which the e-book resources could help them solidify concepts and skills, they eventually became more concerned with their course grade. We believe that students still need to be convinced that the interactive figures are worthwhile to use, and that adjusting their studying techniques in order to incorporate such tools is meaningful and worth their time. Table 5, which concerns whether students would recommend using an e-book versus this e-book, contains data that suggests an initial step in this direction. Since students reported few previous experiences with e-books, we see their willingness to recommend this particular e-book over their perceptions of a generic e-book as indicating improvement in their view of the value of these novel features.

While the majority of students reported little use of the interactive figures, *the students who did make use of the interactive figures also reported gaining conceptual understanding from them.* This correlation is shown in Figure 1. It is unclear from our data whether these students used the interactive figures more because they found them useful, or whether these students found the interactive figures more useful because they used them more. In either case, a subset of the class found that the interactive figures were useful and effective as a learning tool. We take this to mean that the interactive figures do hold promise for supporting conceptual understanding for at least some students, and it may be possible to increase the proportion of students who find them helpful.

Rather than the interactive figures, however, *the most popular feature of the e-book among our students was the homework helper, a component of an online homework system that was paired with the e-book.* In addition to the data in Table 1 and Table 4, of the 33 students who responded to the free response question—"What was the most helpful component of the e-book?"—on the final survey, 25 mentioned the study devices that are part of the homework helper. Even by the middle of the term, students were articulating this sentiment. In focus groups, students across both sections offered the interactive figures and the online study tools as aspects of the e-book that were enhancing their learning, but they responded individually much more favorably about the online study tools. We see this not as students rejecting the utility of the interactive figures (indeed, few students disagreed that the interactive figures were enhancing their learning), but rather as students articulating their priorities. Students saw the homework helper as the most relevant tool to help them achieve their top priority in the class: a good grade.

Preference for the homework helper over the interactive figures as the most popular feature of the e-book was less articulated in Section A, however. We see two possibilities for this. First, the students in Section A simply were more receptive to using an e-book. Although the e-book was introduced in the same way to both

sections, Section A had a warmer initial reaction (an average score of 3.57, versus one of 3.36 for Section B). Section A also planned to read the e-book more from the beginning (3.29 versus 2.50). Second, some differences may be a result of having different instructors. We note especially that the instructor for Section A actively encouraged students to use the interactive figures while studying on their own. In the end, students in both sections reported a similar drop from their initial reaction to their overall experience (.21 and .27 points, respectively). However, students in Section A had more positive (as well as simply *more*) experiences with the interactive figures while students in Section B reported a greater preference for the online assessment tool and study devices. Investigating reasons for such differences is an important research question for determining how to get students to use interactive figures more effectively.

In order to further address the underuse of the interactive figures, it may be necessary to change the types of assessments we ask our students to complete. In this study, we maintained a rather traditional plan of assessment: a large portion of the students' grades was determined by their performance on quizzes and tests, which were comprised of problems similar to those that students encountered on homework assignments. Including questions or forms of assessment that necessitate the type of conceptual understanding supported by the interactive figures would, in our estimation, help students value these tools. This parallels a suggestion by Selden and Shepherd [9] for instructors "to ask more conceptual and integrative questions on assignments and tests in order to encourage students to read the exposition [in (physical) mathematics textbooks]." If students are able to connect the interactive figures with their own set of objectives for the course, they are much more likely to make use of them. As noted in [9], we believe this is an area for more research.

Another note of interest is that out of 16 students who initially planned to print at least some sections of the e-book, only 1 reported having printed any sections at the end of the semester (and 1 student bought a physical copy). Despite numerous studies showing students' preference for physical texts over e-texts (e.g. [1],[8],[13]), this suggests that most students are not willing to go very far to convert electronic text to a physical format.

4. Instructor Reactions

In this section, we offer some of our reactions as instructors to using the calculus e-book in our classes. The second author of this article was the instructor for one section of this course, and the third author used the e-book as the primary textbook for a differential calculus course during the previous summer quarter. Below, we address three aspects of our experience: implementation of the e-book, the interactive figures, and effective usage.

4.1. **Implementation.** Like any other online resource, implementing an e-book requires advance technical work for both the instructor and the students. Most e-books of which we are aware, including the one used in the present study, require students to establish an online account with the publisher where they can access the text. For the e-book used in this study, students had to also download a (free) software package in order to view the text. These online accounts often host a homework platform as well. Thus, internet access is a requirement both to see the text and to complete homework assignments. For us as instructors,

getting students to establish their personal accounts and download the necessary software package was relatively straightforward. We did have students, however, who reported problems with creating accounts. Throughout the course, students also reported instances when the online system was slow or completely down, which effected their ability to access the text and to complete homework assignments in a timely manner. In short, supporting information technology remains a challenge in the implemention an e-book.

Technology was also a plus in implementing an e-book. Having access to a "smart classroom" improved the quality of our instruction. We found it very helpful to use interactive figures and other components of the e-book during class sessions, both as a way to convey ideas in a lecture and to introduce students to how they might use the technology outside of the classroom. There were also challenges in this regard; using the interactive figures during class sessions required that the classroom be equipped with a projector and an overhead screen, as well as a computer with internet access and the requisite software already installed. Additionally, in order to make use of a chalkboard or a document camera (often the primary media used for lecturing), switching between the two needed to be efficient and relatively seamless. For us, this meant securing the right room for our class and adjusting our lecturing to accommodate the setup of the classroom. We imagine that this could be very difficult to do in many current college or university classrooms.

4.2. **Interactive Figures.** We strongly believe that interactive figures are one of the most promising components of a calculus e-book. Our students were also very enthusiastic about this feature at first, but over the course of the quarter their enthusiasm waned and they used the figures less and less. Despite this trend in student use, we found the interactive figures to be extremely beneficial during class sessions to engage students and enhance their learning, especially when there was a need for visualization.

For example, translations of a graph for a given function can be difficult for some students to comprehend—particularly for students just beginning differential calculus—when only a couple of static drawings are provided. Interactive figures allowed us to show how the graphs of $f(x+c)$ or $f(x)+c$ compare to the graph of $f(x)$ while varying c continuously, providing an experience of shifting graphs of functions left and right and up and down, instead of only being told the results. Likewise, the definition of $\lim_{x\to a} f(x) = L$ is notoriously difficult for calculus students to understand. The interactive figures allowed us to demonstrate shrinking an interval defined by δ so that the graph of the function over that interval fits within a given ϵ interval, and thus, giving a non-computational experience of what the definition means. Another example we found particularly helpful in conveying derivatives as functions is a graph that allows you to show any combination of a polynomial $f(x)$, its derivative $f'(x)$, and second derivative $f''(x)$. The viewer then can play an animation in which a tangent line to f is displayed at point x (continuously varying x), lining up with the point $(x, f'(x))$ on the graph of the derivative, and a description of the properties of the functions at that point are displayed (e.g. $f''(x) > 0$, f' increasing, f concave up).

Students seemed to appreciate these demonstrations, and some informally remarked about how useful interactive figures were to their classroom instruction. Given this, we find it a little surprising that so few students took advantage of the interactive figures while studying on their own.

4.3. **Effective Usage of the E-Book.** Even though our current undergraduate students are very technologically-savvy, they were brought up studying out of physical textbooks. Physical textbooks, therefore, are easy for students to use and students are used to using them. E-books, as we have found, can be challenging for students to use effectively. Many students simply avoided using the new format for studying calculus. Our impression from talking to students is that they used the notes that they took during class sessions more than they used the e-book. We also know from the course website data that they logged into their accounts mostly for the purpose of completing their homework assignments. Worse than students not using the e-book, however, was students misusing it. Some students regressed in their studying habits with the new technology. Although students liked the immediate feedback that the online homework system, some were tempted by virtue of the format (e.g. clicking on a multiple-choice response, entering a number into a box) to try to work problems out in their head without writing anything down—even though we warned against this! As a result, these students were not well-prepared for quizzes and exams, where a written record of one's thought process is an expectation.

In order to take advantage of the unique affordances of a calculus e-book, then, students need to be educated on how to use it. Students also need to understand how using an e-book and all of its features to their full advantage will benefit their learning and conceptual understanding in the short and the long terms. This is a learning process for both instructors and students, but one that, we hope, will prove worthwhile.

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