# Experiences Using a Collaborative Electronic Textbook: Bringing the "Guide on the Side" Home With You

Ryan McFall
Department of Computer Science
Hope College
Holland, MI 49423
1-616-395-7952
mcfall@cs.hope.edu

Herbert Dershem
Department of Computer Science
Hope College
Holland, MI 49423
1-616-395-7508
dershem@cs.hope.edu

Darcy Davis
Department of Computer Science
Youngstown State University
Youngstown, OH 44504
1-330-941-6150
dadavis.01@student.ysu.edu

## Abstract
Much has been made of the transition of the instructor's role from "Sage on the Stage" to "Guide on the Side", focusing on active and collaborative learning in the classroom. The process of acquiring knowledge from textbooks has largely remained unaffected by this transition. Our work on electronic textbooks (e-textbooks) has focused on building e-textbooks that extend the reach of collaborative and active learning techniques to the reading process. This paper describes the outcomes of using our e-textbook in a one semester course on programming language design and implementation, including the impact on student learning, the degree to which they took advantage of the e-textbook's collaborative and active features, and their reaction to the use of the e-textbook as the primary text resource.

## Categories and Subject Descriptors
K.3.1 [**Computer Uses in Education**]: Collaborative Learning, Computer Assisted Instruction

## General Terms: None

## Keywords: electronic textbooks, active reading

## 1. Introduction
In today's educational environment, there are many options for how information and concepts can be presented to learners. The proliferation of multimedia has introduced new ways of conveying information, often involving an element of interactivity that can help students engage and wrestle with concepts. The emergence of the World Wide Web as a source of information, particularly when combined with the support of a good search engine, has also changed the way that learners obtain information. However, acquiring information and integrating new concepts and ideas into one's knowledge base from traditional textbook-like sources is still an essential skill in today's society. Multimedia resources are time-intensive to create, and many learners and teachers do not make use of these resources even when they are provided [1]. Finding credible resources on the Web can be difficult, and the search-driven nature of much of the web's use is not really appropriate for learning. In our opinion, the traditional textbook remains the best vehicle for content dissemination.


*SIGCSE'06*, March 1–5, 2006, Houston, Texas, USA.


However, the textbook is not without its problems. It has become increasingly difficult to find a textbook that covers a topic at the breadth, depth and level of detail appropriate for a particular course. E-textbooks have often been cited as having the potential to address some of the paper textbook's shortcomings. We believe that in order for e-textbooks to be successful, they must find ways to take advantage of the e-textbook's digital nature to enable new learning techniques that are not possible with its paper ancestor.

This belief led to the development of our e-textbook application. This paper's goal is not to discuss the design goals and features of our e-textbook; for a detailed description see [2]. However, the most important features are outlined in the list below:

- **Shared annotations**: our e-textbook seeks to allow interaction among students and between students and their instructors directly within the textbook through the use of shared annotations, which include *textual notes*, *diagrams* and interactive *discussion forums*.
- **Extending traditional techniques**: for example, colored highlighters are given names, and students can see all the passages highlighted with a given highlighter.
- **Shared bookmarks**: students and instructors can create named bookmarks in the text; instructors can share bookmarks with the class, pointing them to specific passages, or to outside resources. One particularly useful shared bookmark is the *reading assignment*, in which the instructor indicates a passage to be read for the next class period, with a status indicator students use to monitor their progress.

Our previous experience with the e-textbook was in an CS0 course, the details of which are reported in [3]. The reaction to the e-textbook in this course was somewhat ambivalent. For several reasons, we believed that a further evaluation in an upper level course would yield more positive results.

There are several reasons why we were optimistic that the e-textbook would have a more significant impact in this evaluation. First, students in this course were likely more motivated, and more comfortable with the application's technical nature, making them more willing to experiment. Second, more explicit effort was made by the instructor to change the nature of the classroom interaction through the use of the e-textbook. In particular, the instructor used online discussion to employ more of a "just in time" teaching methodology [4]. Finally, the maturation of the tablet PC (for which our application is optimized) allowed us to improve the e-textbook's performance significantly

The remainder of this paper will first outline related work, then describe our study, its results, and some conclusions drawn from those results.

## 2. Related Work

There have been several commercial e-book applications. Some have been more general e-book readers, such as the Rocket e-book (now defunct), while others have focused on textbooks; for example, the GoReader (now defunct) and more recently, SanDisk's BookLocker [5] product. Vendors have frequently focused on decreased cost or weight, and have not focused as much on improving the textbook. Most systems include the ability to highlight, search and annotate text, but have not really extended these capabilities to include sharing of these annotations.

The Adaptive Book project [6] at Carnegie Mellon University is very similar to our current work. The main difference between our application and the Adaptive Book seems to be in the implementation of shared annotations (grouped together into "markups" in the Adaptive Book) are shared.

A few studies have evaluated students' impressions of these systems in actual classroom situations [7, 8]. The most interesting of these is the LiveBook [9], which seems to support many of our e-textbook's features. At the time of this writing, details on the research evaluating the LiveBook do not seem to be available.

Much work has focused on using and evaluating online discussions [10, 11]; to our knowledge, no work has focused on integrating discussions into an electronic version of a textbook.

## 3. Experimental environment

### 3.1 Textbook

The textbook used was the pre-publication manuscript of the 3rd edition of Dershem and Jipping's Programming Languages: Design and Implementation. The main reason for this choice was the easy accessibility of an electronic version of the text, as the course instructor was also one of the textbook's authors.

### 3.2 Student Population

13 students took the course, which was divided into two half-semester long parts. All but one of the students took both parts[1]. Three of the students were female, while the rest were male. All were "traditional" students: aged 18-22 and full-time college students. Four of the students taking the course had also participated in the design and implementation of the e-textbook application; one continued to do so during the course of the semester.

One additional student sat in on the course and took part in the evaluation; however, this student did not complete course assignments or examinations, and is therefore not included in the analysis involving course performance.

Each student was given an HP TC1100 tablet PC with the e-textbook application pre-loaded. They were allowed to use the tablet for any purpose they wished, and kept the tablet throughout the duration of the semester.

[1] When looking at log data for this student, we multiplied all associated data by 1/FHP, where FHP represents the percentage of the total time spent reading during the first half of the course by all students. FHP had a value of approximately 52.1%, leading to a multiplier of approximately 1.94

### 3.3 Instructor

This was the instructor's first time using the e-textbook application; he was not one of the application's designers. He had previously taught the course several times.

### 3.4 Data gathering

Data on the e-textbook's use and effectiveness were gathered in several ways. To measure the usage patterns of specific features of the e-textbook, the application maintained a time-stamped log of almost every conceivable event type, such as highlighting, searching, and even scrolling through the text. This log was maintained in a centralized database, and replication techniques were employed to allow log data to be gathered and integrated into the central database even when students worked offline.

The student doing active development of the application during the course offering was somewhat problematic, as it proved difficult to determine which of the log data for this student was associated with reading for the course, and which was associated with development and testing of the new features he was working on. We have not attempted to differentiate these activities in our analysis.

Student performance on traditional assessment instruments such as homework, programming projects and examinations was recorded. The results of these assessments were then correlated with the log information gathered automatically by the software to determine how usage of the e-textbook corresponded to performance on these assessments.

Finally, an online survey was administered to the students to get their assessment of the e-textbook's value, ease of use and impact on learning. In order to allow cross-referencing their responses with their usage of the e-textbook and their performance on the course assessments, these surveys were not anonymous. Students were made aware that their responses were not anonymous.

## 4. Results

### 4.1 Student Perceptions

Student reactions to the e-textbook are an important part of its evaluation; a tool students don't want to use is useless even if it is one of the most effecting learning instruments available.

Table 1 shows students' impressions of the usefulness of the e-textbook and its impact on their learning. As can be seen in the table, a majority of the students rated the textbook as either *useful* or *very useful*. When asked to evaluate the textbook itself, half of the students rated it as about average; however, students rated the electronic features of the e-textbook more highly, with 9 students stating that the electronic nature of the textbook helped them learn a little more than other textbooks. Also of note is the fact that two students did state that the electronic nature of the textbook helped them learn *much less* than other textbooks, while no students rated the textbook itself *much less* useful than other texts. Both of these students' comments about the e-textbook focused on the time it took to perform several tasks.

Features students rated as most useful included searching the text, annotating the text (both using text and digital ink), and the reading assignment bookmarks. A couple students noted that the annotation summary window, which display all the annotations viewable to a student along with the annotations' context, was a great idea, but the implementation was neither user-friendly nor speedy, and so they did not use it.

Noteworthy comments made by the students about the usefulness of various features of the e-textbook include:

- "The feature I found most helpful was the ability to write notes and highlight the reading as I go. In most of my text books, I do not highlight in case I want to sell them back, etc. With the E-textbook, I had the freedom to write all of the notes I wanted."
- "I liked the discussion features and being able to send comments to the instructor"; "I very much appreciated the ability to create and respond to other's discussions"; "I really appreciated the interaction side: I was able to ask questions referring to specific parts of the text, and get an answer/explanation from the prof or other students."

**Table 1: Usefulness and impact on learning**

| How useful was the textbook? | | | |
|---|---|---|---|
| **Not useful** | **Somewhat useful** | **Useful** | **Very Useful** |
| 0 | 2 | 9 | 3 |

| Has the textbook helped you learn less or more than textbooks in other courses? | | | | |
|---|---|---|---|---|
| **Much less** | **Little less** | **About the same** | **Little more** | **Much more** |
| 0 | 1 | 7 | 5 | 1 |

| Has the electronic nature of the textbook helped you learn less or more than textbooks in other courses? | | | | |
|---|---|---|---|---|
| **Much less** | **Little less** | **About the same** | **Little more** | **Much more** |
| 2 | 0 | 3 | 9 | 0 |

Sharing of annotations, both in the form of discussion questions and instructor-to-student shared annotations, is one of the major features of the e-textbook, and so students were asked several questions about the impact sharing had on their learning.

Table 2 summarizes student reactions to the impact of the use of discussion questions. For these questions, students were not asked to consider the integrated nature of the discussions into account; rather they were only asked to evaluate the impact of using discussions, both inside and outside of the classroom.

**Table 2: Effect on learning of discussion and reading questions**

| Significantly decreased | Slightly decreased | No effect | Slightly increased | Significantly increased |
|---|---|---|---|---|
| How did posting responses to discussions affect your learning? | | | | |
| 0 | 0 | 1 | 12 | 1 |
| How did reading others' discussion responses affect your learning? | | | | |
| 0 | 0 | 2 | 11 | 1 |
| How did the use of discussions affect the effectiveness of classroom meetings? | | | | |
| 0 | 0 | 5 | 4 | 5 |

Almost all students found that the use of discussion questions slightly increased their learning in the course. It is interesting to note the number of people who found the use of discussion significantly increased the effectiveness of class meetings.

Students were also asked to evaluate the usefulness of integrating discussions into the textbook (as opposed to an outside discussion board). 7 students rated the e-textbook system as *slightly better*, than an outside forum, while 5 stated that it was *significantly better*. One student rated the outside forum *slightly better*, and one indicated *no difference.*

Finally, students were asked to evaluate the impact on their learning of the instructor's shared annotations (e.g., elaborating on a specific portion of the text or referring them to another resource). 9 students said that instructor annotations *slightly increased* their understanding of course material, while 5 students said these annotations *significantly increased* their understanding. These results seem to validate our hypothesis that extending annotation features to allow for sharing helps students learn.

## 4.2 Comparing Class Performance with E-textbook Use

We performed a number of analyses to assess the impact the e-textbook had on student performance. In order to minimize the impact that working with others had on performance, we used only the students' examination scores to rank their performance.

The first variable we looked at was whether the amount of time students spent with the e-textbook had an impact on their course performance. Determining the exact amount of time spent reading is a difficult task, since reading is a passive task, and there is no real way to differentiate between reading and being "idle", meaning that the user was either away from the computer, or working on some other application on the computer.

We chose to measure reading time as follows. We divided each user's action events into *sessions*, where a session was defined to end whenever the time between two consecutive log events exceeds some threshold (recall that even scrolling is recorded as an event in the log). The threshold value was chosen to approximate how long a user might reasonably spend reading a single page. In all our analyses, we used a threshold value of 5 minutes, and threw out any sessions where the length of the session was 10 seconds or less, as these sessions typically involved the student closing the application after being idle for a long period of time.

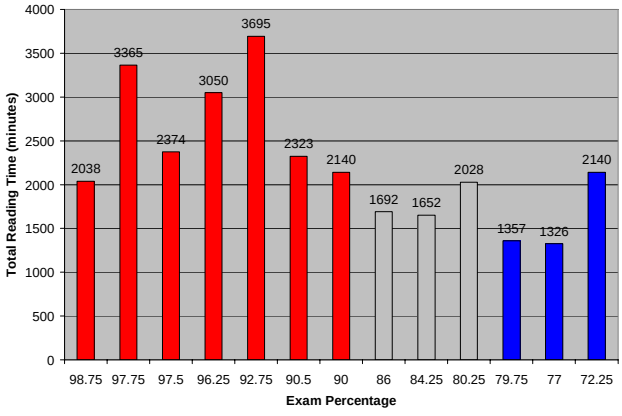


**Figure 1: Comparing Exam Performance to Time Spent Reading**

Figure 1 shows the results of plotting the course performance against the total amount of time spent reading during the semester. The X-axis shows the student's examination percentage, ordered in decreasing order from left to right. The Y-axis plots the number of minutes spent reading the textbook. The student with a percentage of 90% is the student who only completed the first portion of the semester. Shading indicates groups of students in the 90%, 80% and 70% ranges.

Figure 1 does seem to show a trend, with students who performed better on the exams spending more time reading. A logical place to divide the students into two clusters seems to be at the 90% threshold. Doing so breaks the students into two groups: 7 students who achieved exam scores of at least 90%, and 6 students whose exam scores were below 90%.

There are two students in the lower half who spent a good deal more time reading than the other 4 students; interestingly enough, the student who had the lowest exam score spent more time reading than the student who had the highest exam score.

Another interesting metric is the average length of time spent by a student during a reading session. This measures whether or not the ability to stay "on task" while reading is correlated with performance on exams. There was no real correlation between session length and performance. If anything, several of the higher performing students showed a shorter average session length than other students, although the student with the highest average session length had the 2nd highest exam scores. At least in isolation, this particular measurement does not appear to give any information about student performance.

We also tried to determine the impact that the use of the various e-textbook features had on course performance. To do this, we performed a cluster analysis using the k-means clustering algorithm, with the variables comprising the data vector for each student based on the **frequency** each type of event was performed. Frequencies were used rather than raw counts to avoid any correlation with time spent reading. After performing factor analysis to reduce the dimensionality of the problem, and scaling all data to fall within the same range, the k-means algorithm was applied, with the number of clusters set to 3, based on the idea that students' performance might be broken into the 90%, 80% and 70% ranges.

The results of the k-means clustering yielded no significant pattern. Due to the small number of cases given to the algorithm, this is perhaps not surprising. Applying this technique to a much larger data set would perhaps yield some insight.

## 4.3 Usage of E-textbook Features

We examined the e-textbook logs to determine the features of the textbook used most frequently by the students. By far the two most frequently used features were **highlighting** (1317 highlights made) and **searching** (1004 searches performed).

Analysis of the use of highlighting shows students broken into two fairly distinct groups. 6 students frequently highlighted portions of the text, with a range of 132 highlights up to 367 highlights. 8 students used highlights more rarely, with 2 having no highlights at all, and the other six ranging from 8 to 60 highlights. Two of the top five students were infrequent highlighters; the student who created the most highlights actually had the lowest scores of all the students (recall this student also spent the most time reading!)

Examination of the usage of the search feature also yielded some interesting observations. The students could again be divided into two groups based on their number of searches. There were four students who frequently searched through the textbook, with numbers of searches ranging from 128 to 283, accounting for 82% of the total searches. The number of searches for the remaining 10 students ranged from 1 to 56. The 4 students who were frequent searchers were also the 4 students who worked on the project as developers. 3 of these 4 students were among the top 4 students in the course, while one was ranked 8th. The students were chosen as developers based on their academic qualifications, so it is quite possible that the relationship between numbers of searches and course performance was artificial. The developers also had more experience using the search feature as part of their testing, and so they may have been more comfortable using it.

## 4.4 Instructor Perspective

The instructor used the annotation capabilities of the e-textbook in five different ways in the course: (1) expanding on the text, (2) requesting further research into a topic, (3) requesting students to respond to the instructor only, (4) requesting students to submit responses that are read by all members of the class including the instructor and (5) student annotations raising a question or making a point about a portion of the text.

Being able to include his own elaboration to any issue in the text gave the instructor the feeling that he was sitting next to the students while they were reading the text, relating a passage of the textbook to prior classroom discussions, prompting the students to make connections with other materials, and pointing out connections to other parts of the text, with a link included.

Almost daily the instructor placed an annotation next to an item in the textbook that asked a specific student in the class to do further research on some aspect of that topic and to give a two-minute report on the topic to the class during the next period. In this way, the instructor gave everyone in the class an opportunity to do research at some point during the term and could select the class member for whom the selected topic might be most appropriate.

Requesting students to submit responses to the instructor only was the most common mode for homework assignment and submission. The instructor placed an annotation within the text that students would read and that would ask them to respond to either a question asked directly by the instructor or an exercise from the textbook. The student responses would be visible to the instructor only, and the instructor could then reply with a grade and comments as an addition to the thread that only the student could see. This arrangement had several advantages. First, generally no paper was used for the assignment. Second, the student was given the assignment in the exact context of the textbook where it was appropriate. Third, students needed to read through the entire text in order to discover work that was assigned, rather than working from questions and then going directly to the part of the text where that question is answered without ever reading intervening text.

Requesting students to submit responses read by all members of the class was used frequently to great advantage. Although this form of annotation was provided to encourage discussion, this is not what occurred in practice. Because these were daily reading assignments that the students typically completed over a two day span, it was not practical for students to make one pass when they entered an initial response to the annotation and then a later pass when they replied to classmates' initial responses. Instead, the

process was more linear, with each reader building on the responses of those who read and responded before them. When such an annotation developed an interesting diversity of responses, class time was used to conduct a full discussion of the issues. This proved to be very effective.

Students were encouraged to ask questions about parts of the text that were unclear. About two-thirds of the students did this with regularity, while the other one-third seldom if ever took advantage of this feature. The instructor would either respond within the annotation for the entire class to read or, as was most often the case, respond to the annotation during the next class period.

The instructor used the two hours before class to review the annotations made by students. The activities of the class period were then designed in response to these annotations. There were several advantages from the instructor's standpoint. First, the instructor knew before the class period which students had read the assigned reading and which had not. Second, the instructor knew which points of the reading needed further attention and which points the students grasped adequately. Furthermore, the nature of the misunderstandings was clear and students who did understand could be called upon to assist their classmates in clarification. Third, discussions that were begun in the annotations could be continued with all members of the class having already given some significant thought to the topic at hand.

The instructor reported that the use of the e-textbook completely changed the way he taught the class, giving him a better connection to the students and their learning and making his use of class time much more effective. He would not want to return to teaching the class with a traditional textbook approach.

One significant advantage of using the e-textbook is that the tools such as annotations and highlighting are not limited to use on the textbook, but can be used on any web page. In this course, the instructor used this very effectively to assign student readings in various language reference manuals, utilizing the same five techniques discussed previously in the reading assignments from those manuals. The instructor reported that the next time he teaches this course, he will use only publicly accessible web resources and his own annotations rather than a textbook.

## 5. Analysis of results and Conclusions

Our results give cause for guarded optimism about the e-textbook's potential impact on learning. The qualitative survey results almost uniformly indicate the e-textbook's positive impact on students' perceptions of their learning. As there was no control group, it is impossible to determine whether the e-textbook *actually* impacted learning, either positively or negatively.

The analysis of student performance compared to reading habits is certainly interesting, particularly the cases where students either did not spend much time reading the textbook but did well in the course, and those who did significant reading yet still did not fare as well on the course exams. There are several explanations for this phenomenon, with the most likely being that successful completion of the learning assessments used did not necessarily require textbook reading.

The instructor's uniformly positive reaction to the e-textbook is very encouraging, and indicates that using the e-textbook may be beneficial even if evidence supporting its impact on student learning is not found. Certainly the knowledge that students are actually reading the textbook and having an understanding of where misconceptions exist is helpful information to have.

In the future, we hope to be able to evaluate the e-textbook with a larger group, including a control group, giving both sets of students training on active reading techniques beforehand, to help us evaluate whether the electronic enhancements do indeed have a significant impact on learning.

## 6. Acknowledgments

The original work on the e-textbook was supported by an NSF CCLI grant, number DUE-0126486. Darcy Davis' work was supported by an NSF REU grant, number CNS-0353566.

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