Effects of E-textbook Instructor Annotations on Learner Performance

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Abstract

With additional features and increasing cost advantages, e-textbooks are becoming a viable alternative to paper textbooks. One important feature offered by enhanced e-textbooks (e-textbooks with interactive functionality) is the ability for instructors to annotate passages with additional insights. This paper describes a pilot study that examines the effects of instructor e-textbook annotations on student learning as measured by multiple-choice and open-ended test items. Fifty-two college students in a business course were randomly assigned either a paper or an electronic version of a textbook chapter. Results show that the e-textbook group outperformed the paper textbook group on the open-ended test item, while both groups performed equally on the multiple-choice subject test. These results suggest that the instructional affordances that an interactive e-textbook provides may lead to higher-level learning.

Keywords: e-textbook; print textbook; learning; reading comprehension; instructor annotations; experimental study

Introduction

Textbooks are still among the most frequently used teaching resources in college education, and careful reading accounts for 85% of successful learning (Richardson, Morgan, & Fleener, 2012; Simpson & Nist, 2000). Every academic year, students pay more than $1,000 on average to buy textbooks, which adds to the ever-increasing cost of a college education (Bidwell, 2014). Given that some students refrain from buying textbooks due to their high prices, textbooks may actually impede student learning rather than encouraging it (Senack & The Student PIRGs, 2014). As a remedy, educational publishers are now offering electronic versions of textbooks at a lower cost. The research on e-textbook adoption highlights cost benefits as a significant factor contributing to college students' preference for electronic versions; however, e-textbooks may offer more than cost savings. They may facilitate improved teaching and learning via features and interactivity that are not readily available in paper textbooks.

The features offered by newer e-reading software enable students and instructors to interact with an e-textbook in different ways (Walling, 2014). For example, an instructor can share notes and highlights on a reading assignment directly within the e-textbook. One key question is whether these new features affect student learning.

The majority of research on the learning effects of e-textbooks has thus far compared the difference in mediums (i.e., textbooks delivered on paper vs. on screen) rather than examining how the features offered by e-textbooks enable different instructional methods (e.g., Daniel & Woody, 2013; Siebenbruner, 2011; Terpend, Gattiker, & Lowe, 2014). Consequently, previous research has not reported any significant difference

between paper and electronic textbooks because the media alone (paper versus screen) have few distinctions when it comes to learning (Ackerman & Goldsmith, 2011; Connell, Bayliss, & Farmer, 2012). In contrast, this study investigates the learning effects of one feature of enhanced e-textbooks, looking at the impact of instructor annotations on student performance.

Changing nature of e-textbooks

Despite being around for the past four decades, e-books have lacked a persistent definition due to the ever-changing technologies and features through which they are delivered and read (Vassiliou & Rowley, 2008). Therefore, Vassiliou and Rowley suggest a two-part definition that captures both the characteristics of e-books and dynamically changing technologies underlying them. Based on this definition, an e-book:

> 1) Is a digital object with textual and/or other content, which arises as a result of integrating the familiar concept of a book with features that can be provided in an electronic environment, and
> 2) Typically [has] in-use features such as search and cross reference functions, hypertext links, bookmarks, annotations, highlights, and multimedia objects and interactive tools (p. 363)

Compared to e-books, e-textbooks are still relatively new in the marketplace—but they are subject to the same definition. One of the evolving features is interactivity, which Walling (2014) describes on a continuum. On the low end of the interactivity continuum, e-textbooks are digital images of the paper book. Moving from the low end to the high end, e-books and e-textbooks alike offer variety of interactive functions such as highlighting, bookmarking, and annotations. On the high end, enhanced e-textbook reading software offers social networking capabilities such as allowing the instructor and students to share

notes, highlights, and annotations. These capabilities deserve special attention because they have the potential to convert a textbook from a self-study tool into a technology-supported collaborative learning tool, in which notes and discussions are anchored directly to textbook content. And because of these capabilities, e-textbooks are becoming more prevalent in higher education as institutions are increasingly adopting OER and CBE content delivery platforms that incorporate these tools. In the next section, we summarize the research related to e-textbooks with annotation features.

Reading and learning from e-textbooks

Enhanced e-textbooks are delivered through an electronic medium—smartphones, e-readers, tablets, or computers—so research on e-textbooks draws from three different but related knowledge bases: comprehension from screen reading, media comparison studies, and annotations on textbooks. Below we summarize each of these areas in order to establish the theoretical framework for the current study.

Comprehension from screen reading

With the advent of digital media and more information available digitally, people are increasingly spending more time reading from digital displays than on paper. This digital environment is changing reading practices and behaviors. For example, Liu (2005) found that most screen-reading time is spent on one-time, selective, and non-linear reading; browsing and scanning; and keyword spotting. The same study also reports that people still prefer paper for in-depth reading, which usually involves annotating and highlighting.

Previous research on information recall when reading from screen compared to paper media has mixed results. However, most of this research uses a small amount of text,

which is not typical of textbooks for studying course content. Textbooks contain narrative and expository text, from which students are expected to draw conclusions based on careful reading (Margolin, Driscoll, Toland, & Kegler, 2013). Recent studies examining the screen reading of narrative and expository text show that college level readers comprehend the same level of information from screen reading as they do from paper reading (Ackerman & Goldsmith, 2011; Connell, Bayliss, & Farmer, 2012; Eden & Eshet-Alkalai, 2013; Green, Perera, Dance, & Myers, 2010; Indiana State University, 2013; Margolin et al., 2013; Niccoli, 2015).

Learning from e-textbooks as instructional media

As e-textbooks offer an alternative medium to textbooks, it is important to situate the research on learning from e-textbooks in the framework of media comparison studies. In the seminal debate regarding the influence of media on learning, Clark (1983) posits that the medium and the instructional method are two distinct entities. Based on his review of the research, Clark concludes that media never influences learning and any significant difference in learning should be attributed to instructional method. He views media just as a vehicle to transfer information to learners, who he views as passive receivers of information. In contrast, Kozma (1991) describes the relationship between media and method as reciprocal. He argues that "the capabilities [attributes] of a particular medium, in conjunction with methods that take advantage of these capabilities, interact with and influence the ways learners represent and process information and may result in more or different learning when one medium is compared to another for certain learners and tasks" (Kozma, 1991, p. 179). Kozma (1994) also differs from Clark in that he views learning as an active and constructive process.

As highlighted by Kozma (1994) and later reviewers of this debate, the research on learning from media should focus on how media can facilitate learning when used in conjunction with a particular instructional method (Hastings & Tracey, 2004; Morrison, 1994; Nathan & Robinson, 2001). In the last 30 years, we have seen dramatic changes in computer and internet technologies, offering capabilities that can support certain instructional methods in ways that were difficult or effectively impossible without technology. Therefore, research into earlier technologies does not help us assess how new technology such as e-textbooks can facilitate learning and reading comprehension (Kamil & Chou, 2009). As we describe above, e-textbooks have evolved from digital images of textbook pages to include interactivity between students, content, and the instructor. As a result, there is a need for research on how e-textbook features can support learning and reading comprehension.

Although there have been a number of studies focusing on the learning effects of e-textbooks, most of these studies compare overall impact of e-textbooks to paper textbooks (Daniel & Woody, 2013; Giacomini et al., 2013; Ji, Michaels, & Waterman, 2014; Rockinson-Szapkiw, Courduff, Carter, & Bennett, 2013; Shepperd, Grace, & Koch, 2008; Siebenbruner, 2011; Terpend, Gattiker, & Lowe, 2014). The e-textbooks in these studies are mere replacements of the paper textbooks; thus, none of these studies employ an instructional method that can capitalize on features of the e-textbooks. Consequently, and not surprisingly, they do not report any significant difference in learning due to the media, regardless of whether learning is measured with test scores (Daniel & Woody, 2013; Siebenbruner, 2011), course grades (Shepperd et al., 2008; Terpend et al., 2014), or self-

reported learning gains (Giacomini et al., 2013; Ji et al., 2014; Rockinson-Szapkiw et al., 2013).

Only a few studies consider the unique features of enhanced e-textbooks—such as highlighting or annotating—when examining learning differences. Annotations are comments, notes, or external remarks attached to a document (Yang, Zhang, Su, & Tsai, 2011). Adding annotations to a textbook can make a significant contribution to both cognitive and metacognitive aspects of learning. Underlining and highlighting can also assist in recall (Flavell, 1981; Lee, Lim, & Grabowski, 2010). Weisberg (2011) examined student attitudes and behaviors towards e-textbooks over two years using five different e-reader devices and one paper textbook group. There were no learning differences between different e-reader devices or between these devices and the paper textbook group. Although these e-readers included highlighting and note-taking features, the study did not directly examine the use or impact of highlighting and note taking.

In an experimental study, Taylor (2011) treated student engagement with a textbook (clean vs. annotated reading) as one of the main effects for both paper and e-textbook groups. The *clean engagement* group in this study was told not to make any annotations, whereas the *annotated engagement* group was encouraged to annotate the assigned textbook while reading. The study reports no significant differences due to engagement. However, the extent of annotation is unclear, and the study does not note whether the paper and e-textbook groups were combined for the analysis.

Instructor annotations on students' e-textbooks

According to Yang et al. (2011), annotations on a document may help the reader in four important areas: attention, organization, indexing, and discussion. In particular,

instructor annotations available directly within e-textbooks may improve student learning in two ways. First, annotation enables instructors to go beyond textbook content with additional online multimedia resources. Based on extensive research into multimedia learning, Mayer (2009) concludes that students learn better from a combination of words and visuals such as pictures, animations, and videos than words alone—and spoken words coupled with visuals have deeper impact on learning than written words combined with visuals. Richardson et al. (2012) also suggest that textbook information should be complemented with other resources. Second, instructor annotations on e-textbooks create new opportunities for instructor-student-content interaction. With annotations, instructors can offer students insights into their interpretation of and perspectives on the textbook content, thereby making it easier for students to understand and interpret the material. This support can result in learning gains (Gee & Rakow, 1990). Specifically, these insights provide scaffolding beyond formal class time, guiding student efforts to grasp the most critical content. Annotations also enable instructors to model expert practices by making those practices visible to students (Linn & Eylon, 2011).

While little research has delved into the effects of instructor annotations on learning or student engagement with e-textbooks, Dennis (2011) found that 84% of college students reported that instructor annotations on an e-textbook were useful in their learning. Similarly, students reported that they read more and learned more with an e-textbook compared to a paper textbook when their instructor shared annotations and highlights on the e-textbook (Abaci, Morrone, and Dennis, 2015). Unfortunately, neither of these studies examines the content of instructor annotations, which may be a key factor in student assessments of helpfulness. Abaci, Morrone, and Dennis (2015) also conducted interviews

with instructors, who used e-textbook annotations for varying reasons: to provide additional relevant content, elaborate on a particular topic, clarify terminology, or provide their perspective on the textbook content. Their responses suggest that students were more engaged with textbook content when instructors guided student reading through shared annotations and highlights. Nevertheless, the actual impact of instructor annotations on student learning or performance remains to be investigated since these two studies were based on self-reported survey and interview data.

In an attempt to answer the impact of instructor notes on student learning, Murray and Pérez (2011) conducted a quasi-experimental study. They assigned one section of an online IT literacy course an e-textbook, which included supplementary links and short video clips. The control group received the printed textbook without the links or short video clips. The study did not find any difference between the two sections regarding student learning, which was measured by two open-book multiple-choice exams. The annotations in the study—hyperlinks and video clips—offered additional information, but did not guide students on how to use the information. Therefore, more research is needed to examine whether other types of instructor annotations improve student learning.

Purpose of the study

As e-textbook adoption in higher education grows and enhanced features enable more interaction between the students, the content, and the instructor, e-textbooks have the potential to offer more than just static images of pages on a screen. Today's enhanced e-textbooks offer supporting features for instructional strategies that would not otherwise be possible. However, current approaches to studying the learning effects of e-textbooks that

solely compare paper and digital media may overlook the potential effects of these features on learning. Therefore, the research design should take into account the specific features and supporting instructional strategies. As highlighted in the previous section, the research into the effects of e-textbooks with shared annotations has been very limited. In an attempt to fill the void, the purpose of this study is to examine the effects of instructor annotations on student learning as measured by a knowledge test composed of multiple-choice and open-ended questions. Specifically, we aim to answer two research questions:

1. Do students using an e-textbook with instructor annotations perform differently on multiple-choice exam questions than students reading from a paper textbook?
2. Do students using an e-textbook with instructor annotations perform differently on an open-ended exam question than students reading from a paper textbook?

Methods

This pilot study uses a single factor experimental design with two levels: a paper textbook (control) group and an e-textbook (experimental) group (Creswell, 2009). The study collected data from college students on a paper quiz and analyzed it in SPSS v.21.

Participants

Participants in this study were second-year undergraduate students from the business school of a large Midwest public university. Fifty-two students (22 males and 30 females) taking a computer technology course were randomly assigned to one of the two study conditions: e-textbook group (n = 27), or paper-textbook group (n = 25).

Materials

The first chapter of a Data Communications and Networking textbook was used. The paper version was a paper photocopy of the chapter and did not contain any instructor annotations. The e-textbook version was presented on a computer screen using an e-reader software that includes interactive features such as highlighting, bookmarking and annotating, and allows both students and instructor to share their highlights and annotations with others. In the present study, students could create but not share annotations with other participants.

The textbook content for this study is used in a third-year computer networking course. We shared the 13 annotations the course instructor used in the previous semester with the participants in the e-textbook group. Some of the annotations (n = 6) provide guidance regarding where to focus, such as “Read this section lightly” or “This section is very important. Make sure you know it well!” Other annotations (n = 7) are intended for elaboration such as “Standards are key to networking. Without standards, we couldn't have the Internet because every company's network could operate a little differently.” One of the elaborated annotations also includes a link to a four–minute video animation explaining how the five layers of the Internet Networking Model work together to move messages across the Internet. Figure 1 presents an example of the annotated e-textbook page, where the instructor highlighted the section title and left a note to students explaining the importance of this section and providing a supplementary video link.

[INSERT FIGURE 1]

Measures

Learning performance was measured with a 25-item quiz, administered immediately after the reading assignment. All of the items in the quiz came from the Instructor's Manual that accompanies the textbook. Of these items, 24 were multiple-choice questions worth one point each. Thus, the maximum score for multiple-choice questions was 24 points.

There was one open-ended question, designed to test deeper understanding and worth three points. It asked students to "use a diagram to show how the five layers in the Internet model work together to send a message from a client to a server." The answer key allowed for partial points; therefore, students could earn between 0.0 and 3.0 points with 0.5 increments. In order to establish inter-rater agreement, two of the researchers graded this question based on an instructor-generated answer key.

Procedure

Upon arrival at the research lab, participants gave consent and were randomly assigned to either the paper or e-textbook group. Average reading time for the chapter was previously found to be approximately 35 minutes. Therefore, participants in both groups were given 35 minutes to read the assigned chapter to prepare for a quiz. The e-textbook group received one minute of additional preparatory instruction on using the software's basic navigation to read the chapter and review annotations. After reading the chapter, all participants had 15 minutes to complete a paper quiz. During the quiz, neither group had access to the textbook.

Results

In their preliminary analysis, the researchers checked the internal reliability of the multiple-choice questions as well as the inter-rater reliability of the open-ended question between the two graders. Cronbach's alpha for the multiple-choice items was .724, demonstrating good internal consistency (Nunnally, 1978). Intraclass correlation between the two graders of the open-ended question was .964 ($p < .001$), indicating excellent agreement between the graders.

The researchers conducted independent samples t-tests to answer the research questions. They tested the dependent variables *multiple-choice total score* and *open-ended item score* against the assumptions of t-test: normality and equality of variances. Descriptive analysis indicated that multiple-choice total scores were normally distributed. Furthermore, Levene's test of equality of variance was not significant ($p = .471$); thus, equality of variance was assumed. For open-ended item scores, descriptive analysis indicated non-normal distribution. However, the sample size for each group was large enough to proceed with the analysis. Levene's test for equality of variance was significant ($p < .001$); therefore, equality of variance was not assumed, and corresponding test results were reported from the SPSS output.

As Table 1 shows, the independent samples t-test ($df = 50$) did not yield significant results for the multiple-choice total score. That is, students reading the e-textbook chapter did not perform differently on the multiple-choice exam than students reading from the paper chapter. In contrast, the e-textbook group performed better than the paper textbook group on the open-ended item. This difference had a large effect size ($d = .89$) according to Cohen's definition (1988).

Table 1

Means (Standard Deviations-SD), t-values, and significance values for comparison groups

Measure	Paper (n=25) *M* (*SD*)	E-textbook (n=27) *M* (*SD*)	Test statistic (*t*)	Significance (*p*)
Multiple-choice test	12.41 (3.68)	14.04 (4.26)	1.48	.145
Open-ended item	.56 (.67)	1.40 (1.15)	3.19	.003*

* Significant at α =.05

Discussion

Research into e-textbooks' impact on learning is still emerging because new features continue to afford instructors and learners new ways to interact with the text and with each other. This pilot study is among the first to examine the effects of instructor-annotated e-textbook content on student learning. Our results indicate that instructor annotations did not affect student learning as measured by multiple-choice knowledge questions. This outcome is consistent with the prior literature on the learning effects of e-textbooks. However, as we highlighted in our review of the existing research, only one study to our knowledge was conducted at the feature level (Murray & Pérez, 2011). The present study is different in that it includes instructor annotations intended to focus students' attention and elaborate on key points in the text.

This study also measured student learning on an open-ended figural response item, which aimed to evaluate deeper understanding of the Internet message transfer process. Open-ended essay questions in general offer an effective way to assess higher-learning objectives (Reiner, Bothell, Sudweeks, & Wood, 2002). Figural responses are more difficult but slightly more discriminating and reliable than their multiple-choice counterparts (Martinez, 1991). One of the annotations in the e-textbook contained a link to a video demonstration that was specifically associated with the open-ended question. While the e-

reader software does not track whether students watched this video, students in the e-textbook group performed significantly better than the paper textbook group on the open-ended item.

Although this study focused only on instructor annotations, the e-reader software used in this study affords students the opportunity to make their own annotations and share these with others in the class. Making annotations is considered a useful study practice (Lee et al., 2010; Marshall, 1997). Annotating behavior is also associated with in-depth reading, which is important for college courses. By creating annotations, students can revise their prior knowledge as they encounter new ideas and information and as they test their current schema (Bransford, Brown, & Cocking, 1999; Sawyer, 2006). More complex annotation strategies—such as summarizing, paraphrasing, finding examples, and generating questions—contribute to metacognitive monitoring and feedback. These strategies can enhance learners' self-regulation, recall, and comprehension (Flavell, 1981; Lee et al., 2010; Leutner, Leopold, & Den Elzen-Rump, 2007), and improve learning when used in review (Kiewra et al., 1991).

Despite the benefits of annotating for reading comprehension, people annotate less on electronic documents than paper documents because it feels less natural or more distracting to reading (Liu, 2005). In contrast, Abaci et al. (2015) found that students annotate more on an e-textbook than a paper textbook when their instructor also annotates in the e-textbook. Thus, instructor annotations may encourage students to annotate more. As Dobler (2015) claims, students' skill with enhanced features of e-textbooks cannot be assumed based on appearances of being good at using digital devices

and social networking tools. Ultimately, more research is needed to study the impact of instructor annotations on students' annotating behavior.

Finally, sharing annotations in e-textbooks can enable collaborative learning as students engage with content. Students may feel more conceptual control when they share annotations with each other (Greeno, 2006). Compared to traditional forum discussions in a Learning Management System (LMS), van der Pol, Admiraal, and Simons (2006) found anchored discussion, another type of shared annotation, more efficient and "to-the-point." Other research also indicates that collaborative annotation is positively associated with learning and reading comprehension (Chen & Chen, 2014; Nokelainen, Miettinen, Kurhila, Floréen, & Tirri, 2005). Research on the effects of shared student annotation on interaction and learning is just emerging. In Giacomini et al. (2013), college students reported no change to their interaction with the instructor or with other students despite the collaborative annotation features of e-textbooks used in the study. However, students rated collaborative features with the lowest priority among other features of e-textbooks. More recently, Hwang and colleagues found that effective in-class text annotation by six-grade students improve learning achievement (Hwang, Liu, Chen, Huang, & Li, 2015). In addition, high-achieving learners create more in-class text annotations and more after-class voice and text annotations than low-achieving students. Additional research with students using collaborative annotation is needed to understand the effects of shared student annotations at the college level.

Limitations

Although experimental design is a powerful research method to confidently attribute outcomes to treatment factors rather than extraneous factors, it is often difficult to establish true experiments in natural educational settings over the course of a semester. In this pilot study, we were able to assign students to experimental and control groups. Nevertheless, our relatively small sample size may have influenced our results. A larger sample size would have allowed us to capture significant differences even with smaller effect sizes. In addition, the e-reader software, at the time of this study, was not able to capture whether students read the instructor notes or watched the external video link. Having the ability to trace student behavior with annotations, we could have claimed more confidently that two groups equally performed on multiple-choice even when e-textbook group attended to instructor notes. Similarly, we could have identified whether the video link caused the significant difference in open-ended item performance. Therefore, future replications of this study should consider (a) a larger sample size, (b) tracing students' behaviors with instructor notes and external links, and (c) measuring the differences over the course of a semester. From an external validity standpoint, our results can only be generalized to students in technology courses in business school. Future replications should extend this study to other disciplines.

Ideas for Future Research on E-Textbook Features

We believe that there is merit to discussing research ideas on e-textbook features beyond those that address the limitations of this study because research in this area is relatively new. The scope of this study was limited to the existence of (or lack thereof)

instructor annotations. As we noted earlier, content of the instructor notes and how an instructor integrates these annotations into his/her teaching could be an important determinant of student engagement with annotations. Future studies should investigate how student outcomes vary based on the type (e.g., study guide, elaboration, and links to multimedia resources) and use of instructor annotations.

Today's online e-reader software can capture all instructor and student behavior with e-textbooks, which can lend to data-rich, unobtrusive research on reading with e-textbooks. It is encouraging to see that research using e-textbook usage data has already started. Junco and Clem (2015), examining e-textbook usage metrics such as number of pages read, number of mark-ups (i.e., highlights, bookmarks, and notes) and time spent reading, found that amount of time spent on reading is a stronger predictor of course outcomes than previous academic achievement. Similarly, Van Horne, Russell, and Schuh (2016) studied the adoption of mark-up tools by students and reported that students are still in the early adoption phase with e-textbook markup tools; highlighting is the only tool used by more than half of the students in the study. More interestingly, they found that the interaction between bookmark usage and amount of reading was positively correlated with course grades. The authors also suggest that students may need more scaffolding by their instructors for the adoption of interactive e-textbook tools. Therefore, future studies should examine student usage of e-textbook features in conjunction with instructor usage for a possible interaction between the two. Furthermore, as e-textbook readers allow for sharing of the mark-ups among students, student interactions with e-textbooks can be studied from a collaborative learning theory perspective.

All in all, studies comparing e-textbooks to paper textbooks (including the current study) have shown that learning is not hindered by e-textbooks even when e-textbooks have limited interactive features or features are used on a limited basis. Future research should focus on how e-textbook markup tools are used both by instructor and students rather than comparing reading between paper and electronic mediums.

Conclusions

Along with cost savings, enhanced e-textbooks offer features that enable the instructor and students to interact with each other through notes shared directly within the textbook. Most of the existing research on learning with e-textbooks has compared only the difference between mediums, while overlooking features that can support instructional methods not possible with paper textbooks. As Jabr (2013) posits, perhaps we should not try to mimic reading on paper while digital technologies can turn screen-based reading into an entirely different experience utilizing interactive features. The findings from this study suggest that instructor annotations on e-textbooks—guiding and elaborative notes as well as links to additional resources—may improve higher-level learning. Although this study only examined instructor annotations, the affordances that interactive e-textbooks provide can create a collaborative environment conducive to learning.

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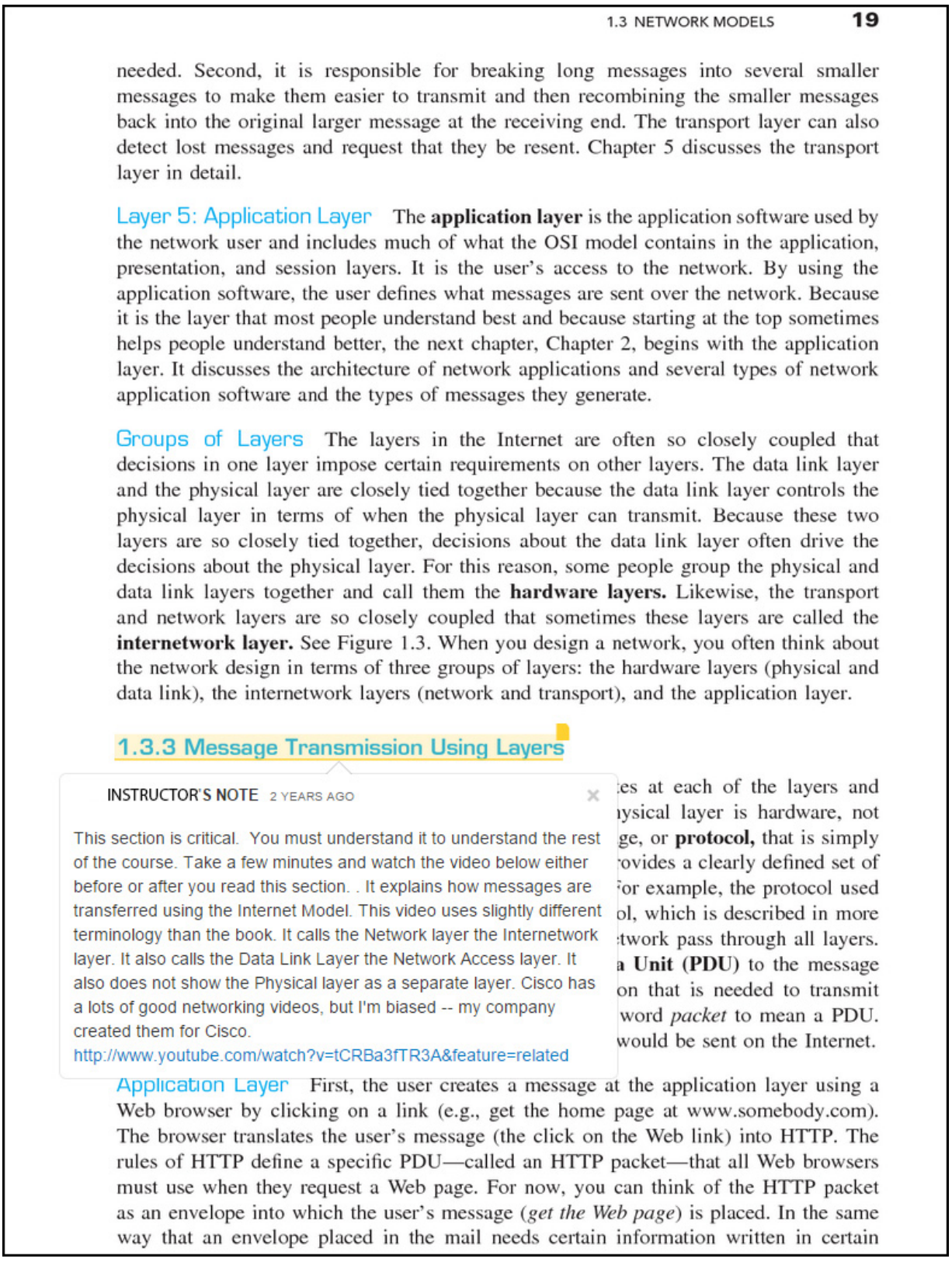
Figure 1 Sample of an e-textbook page with instructor annotation



1.3 NETWORK MODELS 19

needed. Second, it is responsible for breaking long messages into several smaller messages to make them easier to transmit and then recombining the smaller messages back into the original larger message at the receiving end. The transport layer can also detect lost messages and request that they be resent. Chapter 5 discusses the transport layer in detail.

Layer 5: Application Layer The **application layer** is the application software used by the network user and includes much of what the OSI model contains in the application, presentation, and session layers. It is the user's access to the network. By using the application software, the user defines what messages are sent over the network. Because it is the layer that most people understand best and because starting at the top sometimes helps people understand better, the next chapter, Chapter 2, begins with the application layer. It discusses the architecture of network applications and several types of network application software and the types of messages they generate.

Groups of Layers The layers in the Internet are often so closely coupled that decisions in one layer impose certain requirements on other layers. The data link layer and the physical layer are closely tied together because the data link layer controls the physical layer in terms of when the physical layer can transmit. Because these two layers are so closely tied together, decisions about the data link layer often drive the decisions about the physical layer. For this reason, some people group the physical and data link layers together and call them the **hardware layers.** Likewise, the transport and network layers are so closely coupled that sometimes these layers are called the **internetwork layer.** See Figure 1.3. When you design a network, you often think about the network design in terms of three groups of layers: the hardware layers (physical and data link), the internetwork layers (network and transport), and the application layer.

1.3.3 Message Transmission Using Layers

INSTRUCTOR'S NOTE 2 YEARS AGO

This section is critical. You must understand it to understand the rest of the course. Take a few minutes and watch the video below either before or after you read this section. . It explains how messages are transferred using the Internet Model. This video uses slightly different terminology than the book. It calls the Network layer the Internetwork layer. It also calls the Data Link Layer the Network Access layer. It also does not show the Physical layer as a separate layer. Cisco has a lots of good networking videos, but I'm biased -- my company created them for Cisco.
http://www.youtube.com/watch?v=tCRBa3fTR3A&feature=related

es at each of the layers and ysical layer is hardware, not ge, or **protocol,** that is simply ovides a clearly defined set of or example, the protocol used ol, which is described in more twork pass through all layers. **a Unit (PDU)** to the message on that is needed to transmit word *packet* to mean a PDU. would be sent on the Internet.

Application Layer First, the user creates a message at the application layer using a Web browser by clicking on a link (e.g., get the home page at www.somebody.com). The browser translates the user's message (the click on the Web link) into HTTP. The rules of HTTP define a specific PDU—called an HTTP packet—that all Web browsers must use when they request a Web page. For now, you can think of the HTTP packet as an envelope into which the user's message (*get the Web page*) is placed. In the same way that an envelope placed in the mail needs certain information written in certain