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Print vs. electronic readings in college courses: Cost-efficiency and perceived learning

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ABSTRACT

We report surveys of 101 students in two undergraduate college courses about their use of required readings accessed via a university-administered electronic reserve system. About two-thirds of respondents printed at least some readings, although nearly half of the total pages were read online. Most students who printed incurred substantially lower total costs (in terms of both direct printing expense and time opportunity costs) than the projected price of a printed and bound coursepack with all of the readings—thus suggesting electronic provision to be cost-efficient for most students. Respondents reported an overall preference for electronically supplied readings. The advantage of electronic reserves was overwhelmingly perceived to be cost, but large majorities said they usually read more, and learned more, when printed readings are supplied. These findings suggest that university and student incentives to employ electronically supplied readings may be misaligned.

1. Introduction

Technology, cost, and political pressures are driving a strong trend throughout higher education toward the use of e-texts or other electronically accessed reading resources, such as electronic reserves or posted URLs (Buczynski, 2007; Murray & Pérez, 2011; Young, 2010). These changes are occurring both in face-to-face courses and perhaps to an even greater extent, within e-learning or blended learning environments (Murray & Pérez, 2011; Rogers et al., 2011; Thomsett-Scott & May, 2009). Possibly contributing to the pace of change, administrators often seem to assume that electronic reading resources are not only cheaper, but that they are superior for learning (or are rapidly becoming so) as digital natives continue their inevitable march into post-secondary student bodies.

This article is concerned with two broad debates about whether these assumptions are realistic. The first and most general question has been actively explored in the academic literature for more than two decades: Do electronically accessed readings lead to more effective, or less effective, learning than do print based readings? The second question, much less frequently discussed in the academic literature: Is the use of electronically accessed readings a more cost-effective and economic welfare enhancing way to provide students with readings, than is the use of ready-made print resources? The answer to the latter question may seem obvious. To the extent, however, that students may choose to print off the electronically accessed resources for later use, the money as well as time resources they expend could outweigh savings from reduced publisher and book seller costs.

We address aspects of these questions with surveys of 101 undergraduates enrolled in two Indiana University at Bloomington courses in fall, 2010, one a social science-oriented course in the Dept. of Telecommunications, the other a Dept. of Biology course. Both courses supplied all required readings in freely available electronic form via an electronic reserve (e-reserve) system administered by the Indiana University Libraries. Our surveys questioned students on their printing and reading behavior in these particular courses, and collected information about the students and their general preferences for, and attitudes toward electronic vs. printed readings. Using these survey and related data, we directly evaluate the economic efficiency issue in terms of the time and money costs of student self-printing and binding activities. By also providing a detailed picture of student use of an e-reserve system, as well as student attitudes toward printed vs. online readings, we inform the learning efficacy debate.

2. Literature review and research questions

2.1. Studies comparing use and learning efficacy of electronic vs. print resources

A number of studies in the education, psychology, computer science and library science literatures have reported on experiments or surveys that investigate student preferences for electronic vs. print-based library reserves, for online (or on-screen) vs. printed course readings, the behavior of students in using electronically accessed compared to printed resources, and on the learning efficacy of these alternatives.

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Most of these studies have been surveys conducted within traditional face-to-face, online, and blended learning courses, or in some cases, laboratory experiments.

After electronic reserves (e-reserves) began to replace print-based library reserves in the 1990s, several authors reported on surveys showing strong student preferences for electronic over print-based library reserve systems (Austin & Taylor, 2007b; Isenberg, 2006; Pilston & Hart, 2002). Hughes (2004) and Austin and Taylor (2007a) also found that students printed extensively from the e-reserve systems. Austin and Taylor (2007b) reported that students were more likely to read electronically-supplied rather than print-based reserve materials, but this comparison apparently incorporated student printing or copying from either resource.

Turning to the comparison of e-reserves with coursepacks, hardcopy texts, or other printed course readings available for purchase, published studies have consistently found that students prefer to read and study printed rather than on-screen materials. In an early survey of the literature, Dillon, McKnight, and Richardson (1988) reported that reading from computer screens was slower, more fatiguing, had decreased comprehension, and was rated as inferior by readers. They also cited evidence that image quality of the screen display was a crucial factor, thus suggesting the potential for technology to bridge the gap.

More recent studies, however, have found a persisting gap in favor of print for generally similar reasons, in spite of obvious technological advances in onscreen presentation. In a survey of graduate students from 11 different face-to-face classes, Chang and Ley (2006) found that a high percentage preferred to read print. Spencer (2006) reported a survey of distance education students showing preference for printed text materials for reasons, among others, of portability, flexibility, and less eyestrain. Precel, Eshet-Alkalai, and Alberton (2009) found that a majority of college students in a blended learning course who could freely migrate between a printed and digital text, used the printed text more often and believed that it contributed more to their learning. In a large scale nationwide Canadian study of e-learning, more than 80% of surveyed college students reported a preference for reading in print rather than on-screen (Rogers et al., 2011). In a series of face-to-face classroom study and testing sessions, Garland and Noyes (2004) found information retrieval from on-screen reading to be generally slower and less accurate than reading print. In a diary-based study of college students' general reading habits, Foasberg (in press) found that subjects tended to use electronic media for shorter, non-academic reading, but that they did not wish to switch to electronic media for academic reading.

Among other studies reaching similar conclusions based on surveys or on classroom experiments in which students are able to choose between using a textbook in printed or in e-text form, are Buzzetto-More, Sweat-Guy, and Elobaid (2007), Ismail and Zainab (2005), Annand (2008), Vernon (2006), and Robinson (2011). Among reasons cited by these authors for student preferences for print were easier use of multiple resources at the same time, easier future use, and a belief that print enhanced comprehension. Based on a survey of undergraduates, Woody, Daniel, and Baker (2010) noted the well-known historical gender differences in computer use, but reported in their survey that students preferred printed texts over e-books regardless of gender, computer usage rates, or comfort with computers.

In spite of these preferences for print, several authors (including Annand, 2008; Daniel & Woody, 2013; Chang and Ley, 2006; Murray & Pérez, 2011; Spencer, 2006) report finding no significant differences in learning efficacy between on-screen and print users in classroom experiments. Annand (2008), for example, measured student performance in an introductory financial accounting course, and using pre-test controls as a benchmark, found no significant differences in final grades of students who chose to use an e-text compared to those who chose the printed version.

It is difficult, however, to obtain conclusive measures of learning efficacy outside of a laboratory environment. To measure learning differences in such a lab experiment, Ackerman and Goldsmith (2011) found that when subjects regulated their own study time, those reading print performed better on comprehension and retention tests than did on-screen readers. (see also Ackerman, 2009; Ackerman & Goldsmith, 2008). They attributed these differences to "metacognitive" factors; on screen readers had more erratic study time and were less able to evaluate how much they had learned, both of which tended to diminish test performance. Daniel and Woody (2013) examined learning efficacy of printed text vs. e-text readings in both lab and at-home conditions. Although they found no significant differences in learning, e-text reading times were significantly longer than for printed texts, especially for subjects in the at-home condition, who notably reported significantly higher levels of multi-tasking than did lab respondents.

Related to these findings, some authors have also found that when given the opportunity, substantial numbers of students choose to print off e-text or other electronically accessed readings for later use. Chang and Ley (2006), for example, reported that about two-thirds of their survey respondents said they printed 75% or more of online class reading materials. Vernon (2006) reported that a majority of 23 students in a course with only electronically supplied readings initially available relied on making paper copies, with only about 20% reading everything in electronic form.

There are indications from previous research that student preferences for print, along with advantages that print-based learning may have over electronics-based learning, are likely to diminish in the future. Ismail and Zainab (2005) found that previous experience with e-books reduced preferences for printed textbooks, although to a relatively minor extent. Eshet-Alkalai and Geri (2010) report an experiment with 11th grade high school students in which they found a negative effect of "incongruous" forms of onscreen reading (i.e., on-screen displays of materials that were originally designed to be read on paper, such as electronically scanned books), suggesting that continuing transition to computer-generated e-text and other reading materials will diminish the print advantage. In addition, Ackerman and Goldsmith (2011), Robinson (2011), and Woody et al. (2010) all report that students tended to underutilize various enhanced features of e-texts or other on-screen readings, such as digital highlighting and note taking. A recently completed five-university e-text pilot study reportedly reached a similar conclusion (Internet2, 2012; Chen, 2012).

2.2. Economic efficiency

Questions of the economic efficiency of print vs. on-screen readings have not, to our knowledge, been systematically studied, with the exception of Annand (2008), who compared the costs per student of providing an e-text vs. a printed version of the same textbook under alternative assumptions about class size.

Of course, if students read and study an assigned article or e-text online, that saves distribution costs by reducing paper and other physical costs, such as production and sale of a hardcopy coursepack. Similarly for e-texts, which avoid physical duplication and distribution costs.

To the extent, however, that students may simply print off electronically supplied materials and read them later, provision to all students of published hardcopy text materials could be more economically efficient. In classic articles in the economic literature, Besen (1986) and Besen and Kirby (1989) compared economic welfare in a model of centralized duplication and distribution to consumers of a printed product (e.g., a book) by a commercial publisher vs. a model in which the same consumers individually obtained a single master and all made their own photocopies. They showed that centralized duplication and distribution are more socially efficient than individual copying if the publisher has lower duplication and distribution costs than do the copiers—each of whom must obtain the original, then incur time and money costs to duplicate the original.

While Besen wrote over 20 years ago, a modern interpretation of his work is that to the extent students simply print off e-text or other

electronic resources, such as those offered on e-reserve systems, the result may be an inefficient shift of the burden of duplication from publishers to students. Depending on out-of-pocket printing costs and the opportunity costs of students' time, the end result of electronic instead of print provision could also be greater rather than reduced costs to students, and/or possibly lower quality learning materials (i.e., a stack of loose paper v. a professionally bound volume), and from that perspective, be socially undesirable.

2.3. Research questions

Previous research leads us to focus on two main questions in the present study. The first, inspired by Besen's theoretical research: Are reading resources provided to students by means of a freely accessed e-reserve system (or via provided URLs) more or less cost-efficient for students in terms of their time and money costs, than providing the same readings for purchase in printed form? Second, do students prefer to have electronic or printed readings, and which of these do they perceive to better facilitate their studying and learning? Although the latter question has been addressed by a number of studies cited above, online presentation technology as well as student generations are changing continuously; it is thus important to reassess their findings over time. We also pose these questions in a different choice environment, and we attempt to isolate the effects of costs vs. learning-related objectives on student preferences.

While economic goals may reasonably be secondary to learning efficacy, these questions are inevitably related. The pursuit by students of lower cost text materials, such as e-reserves or e-texts (even if they result in self-printed stacks of paper), could have an end result of either less effective or more effective learning.

3. Methodology

3.1. Participants

We selected two Indiana University at Bloomington face-to-face undergraduate courses: one a relatively large enrollment course in the Dept. of Telecommunications (123 registered students) and the other a smaller enrollment course in the Dept. of Biology (41 registered students) to survey during fall semester, 2010. We also surveyed a third course, but the research protocol was not followed, and we do not report those results. Our primary criteria for course selection were that a majority of required readings be accessible only via e-reserves or posted URLs, and instructor permission for us to conduct the survey and access course materials. In selecting courses, we attempted to achieve a diversity of class size and subject matter to the extent practical.

3.2. Materials

All of the required readings in both of the surveyed courses were posted to the IUB Library's e-reserve system, which allows enrolled students password access to electronically scanned or directly uploaded reading materials. In the Telecommunications course, there were 517 pages of various articles and book chapters, plus 19 pages of exams and assignment related materials. The Biology course contained 217 pages of required readings in the form of articles and book chapters; in addition, there were 431 pages of previous exams, lecture notes and other non-required reading materials. There were no printed readings in either course.

The IUB e-reserve system posted electronically accessed resources for 527 different courses in the fall, 2010 semester, a substantial percentage of all courses offered on the Indiana University at Bloomington campus. Reading materials were supplied by instructors to the library in the form of hardcopy materials for electronic scanning, or URLs were provided. Ninety-eight percent of all materials posted on the Indiana University e-reserve system come from library licensed databases that allow for the use of reserves. The remaining 2% are used under fair use provisions or by permission from the copyright holder.

3.3. Procedure

We used an online Survey Monkey questionnaire that had been pilot tested in two relatively large Telecommunications Dept. courses in fall semester, 2009, and then refined. The final surveys were conducted in December, 2010, during the next to the last week of each course, and data analysis took place in 2011 and 2012. Participation in the survey was voluntary, with nominal extra credit offered for participation. An alternative activity (e.g., writing a short paper) to receive the same amount of credit was also offered. Students who consented to the survey were sent a URL and given approximately eight days (Dec. 1 to Dec. 8, 2010) to access and complete the online Survey Monkey questionnaire.

After being asked to access and review the course syllabus and the list of required readings, students were guided by step logic through a series of questions in which they were asked to estimate the percentages of the required readings that they had already printed and read, that they had read online so far during that semester, and that they expected to print and read and/or to read online during the remaining week or two until the final exam. To provide ingredients for estimating student time costs for printing (and binding) e-reserve materials, we asked respondents to estimate the time they spent on these tasks, in addition to information about any outside jobs they held and their wage rates. To address learning efficacy, we asked questions about respondents' preferences for electronically accessed vs. print reading resources, and reasons for those preferences. The questionnaire also collected a variety of other information, including basic demographics, GPA, study hours, computer access and proficiency levels, and willingness to pay for a hypothetical printed coursepack.

Further details about the questionnaire are provided as we proceed.

Table 1 summarizes the characteristics of our samples. We obtained 87 responses in the Telecom course and 28 in the Biology course. Fourteen responses were eliminated due to incomplete or contradictory answers, leaving the 101 usable total responses, 76 from the Telecom course, and 25 from the Biology course. Overall, as Table 1 indicates, gender was almost exactly balanced among the 101 respondents, although skewed toward upper grades, with typical age ranges for such undergraduates. Overwhelming majorities owned or had regular

Table 1
Summary of survey sample characteristics.

Items	Telecommunications class	Biology class	Combined classes
Enrollment	123	41	167
Usable responses	76	25	101
Gender (% male/female)	(44.7/55.3)	(64.0/46.0)	(49.5/50.5)
School level (%)			
Freshmen	0.0%	4.0%	1.0%
Sophomore	23.7	12.0	20.8
Junior	42.1	12.0	34.6
Senior	34.2	72.0	43.6
Age (%)			
19–20	42.2%	24.0%	37.6%
21–22	51.3	56.0	52.4
23+	6.5	20.0	10.0
GPA (mean/median)	3.26/3.24	3.42/3.50	3.30/3.30
Hours of study (mean/median)	14.8/13.0	19.6/20.0	15.0/15.0
Laptop ownership/access (%)	98.7/1.3	88.0/12.0	96.0/4.0
Computer proficiency index* (mean/median)	3.73/3.75	3.40/3.25%	3.65/3.50

* The computer proficiency index is based on reported proficiency of using four software applications—Word processing, Excel or other spread sheet, Adobe and HTML. A five point Likert scale measure was used, from 'Not at all proficient' = 1 to 'Very Proficient' = 5.

use of a laptop computer. GPAs and computer proficiency levels were generally comparable between the two classes.

4. Results

4.1. Self-reported habits of printing vs. on-screen reading

Overall, about two-thirds (65.4%) of the 101 respondents (60.5% in the Telecom course, and 80.0% in the Biology course) reported having printing off at least some of the required e-reserve readings for their course. At the time of the study, undergraduate students received a 650 page black-and-white print quota each semester, paid for through the Student Technology Fee, and $.04 per page was charged to students for unlimited additional printing. Respondents reported that a large majority (80.6% overall) of pages that they printed used university equipment subject to the quota, while most of the remainder was printed on a privately owned computer. Printing from e-reserves is relatively easy, but must be done by individual reading posted on e-reserves (there were 29 separate required reading files in the Telecom course and 21 in the Biology course).

Table 2 provides basic summary statistics, in terms of calculated page volume, of how students in these two courses used and intended to use, the required readings on e-reserves. On average, students had printed, or intended to print, about one-third of all the e-reserve readings. Online reading was also very substantial in both courses, accounting on average for nearly half of the assigned reading pages, although respondents also reported that they had ignored or intended to ignore about a fifth of the required readings.

As indicated by the standard deviations in the amount of printing and online reading for both classes, there was relatively large variation in these behaviors across students in both classes. Of all those who printed some material, only nine students reported that they had printed or intended to print all of the required readings (five in the Telecommunications class, four in the Biology class).

To investigate the characteristics of online readers vs. print readers, we constructed an "online reading intensity" index: ORI = the % of required reading pages read/expect to read online − % of required reading pages printed off/expect to print and read. ORI ranges from +100 (if a student has done, and expects to do, all reading online) to −100 (if a student has done, and intends to do, all reading by means of printing from e-reserves and then reading). A relatively broad frequency distribution of ORI is indicated in Fig. 1 for the full 101 samples.

We examined correlations between ORI and selected demographic and other sample characteristics. Table 3 shows significant pairwise correlations, at the .1 or lower significance levels, of ORI with % of online reading (% read/will read online), % of printed-off materials (% printed/will print), male gender and with Adobe skills, one of four components of the computer proficiency index. Males were somewhat more likely than females to be online readers, $r(99) = .18$, $p < .1$, and the ORI correlation with Adobe skill was positive as would be expected, $r(99) = .22$, $p < .05$, since that is the most common program used for online text editing, highlighting, etc. (Very similar correlation levels between "% read online/expect to read online" and the same set of sample characteristics were obtained.)

Table 2
Online reading vs. printing/print reading; % breakdowns by page volume*.

Items	Telecom class	S.D.	Biology class	S.D.	Combined classes	S.D.
Read online	32.2%	31.3	38.0%	36.3	33.7%	32.5
Expect to read online	15.1	18.9	3.7	8.1	12.3	17.5
Total online reading	47.4		41.7		46.0	
Printed and read	18.8	25.8	31.5	31.5	22.0	27.2
Printed/expect to read	4.2	4.2	5.4	8.4	4.5	8.3
Printed/do not expect to read	3.5	8.6	0.4	1.6	2.8	7.6
Expect to print and read	3.8	7.3	9.9	24.1	5.3	13.7
Total % Print	30.4		47.1		34.5	
Do not expect to print or read	22.3	30.8	11.2	24.1	19.5	29.6
Total %	100		100		100	

* See Appendix A for the specific question on which the data in this table are based.

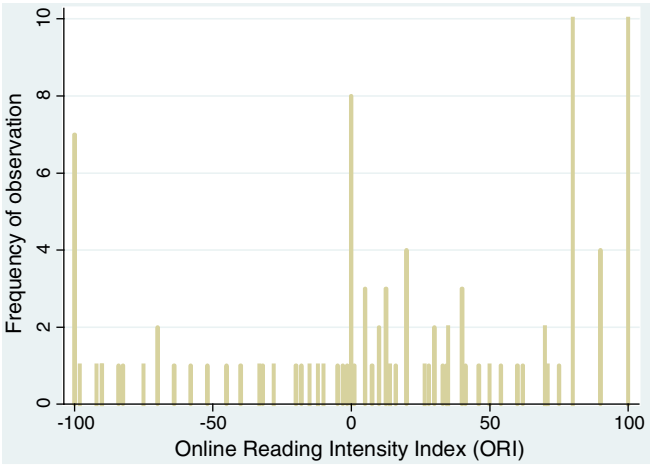

Fig. 1. Frequency distribution of the online reading intensity index (ORI).

To further investigate, we performed a series of ordinary least squares regressions of the ORI index, and of the "% read online" variable, on gender, age, school level, GPA, the computer proficiency index, class level, and various subsets of these variables, for the two separate and the combined courses. In most cases, male gender was significant at the .1 or .05 level, but in none of these variations did the F test indicate a viable model, and we do not report these results.

Overall, then, our results indicate expected, though relatively limited relationships between online reading or printing behavior and characteristics of the survey respondents that we obtained.

4.2. Economics of electronic vs. print resources

As noted above, the two surveyed courses relied on collections of articles and excerpts from books. The two main practical alternatives for the instructors were either to post the materials online in the e-reserve system (or to the course home page as a URL), or to produce a printed coursepack that would contain the readings collection in hardcopy, usually in a spiral bound or similar format. In this section, we evaluate these alternatives from a cost-effectiveness standpoint, though we emphasize at the outset that our comparisons are intended only to be approximate. We also do not directly consider university

Table 3
Online reading index (ORI)[a]: Pairwise correlation coefficients.

Variables	Telecom class	Biology class	Combined classes
ORI	1.00	1.00	1.00
%Read/will read online	0.89***	0.95***	0.90***
% Printed/will print	−0.87***	−0.95***	−0.90***
Word processing proficiency	0.03	0.19	0.12
Excel proficiency	−0.05	−0.16	−0.07
Adobe proficiency	0.25**	0.03	0.22**
HTML proficiency	−0.08	0.26	0.03
Computer proficiency index	0.05	0.11	0.10
GPA	0.02	−0.07	−0.05
Hours of study per week	−0.04	−0.25	−0.14
Age	−0.02	−0.09	−0.12
Gender: Male = 1	0.21*	0.25	0.18*
School level	−0.09	0.10	−0.08
Laptop ownership/access	−0.03	−0.04	−0.07
Base	76	25	101

[a] ORI = number of pages read/will read online − pages printed off/will print and read.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

costs in administering an e-reserve system or any possible subsidies to student printing costs using university printers.

First we draw broad cost comparisons, primarily based on benchmarks for the median respondent in our data. These are summarized in Table 4.

To establish a benchmark comparison of coursepack costs, we obtained by inspection of the prices and page counts of the 25 coursepacks produced by the leading coursepack supplier, "IU ClassPak," (which is owned and operated by Indiana University) that we were able to find on the shelves on one day at the beginning of the semester at the main IUB bookstore, operated by Barnes & Noble. These 25 coursepacks, which ranged in length from 43 to 540 pages, were priced at an average of 26.4 cents per page. A substantial proportion of many coursepacks is copyright fees, which are not separately itemized in the retail prices. We were able to identify 3 of the 25 packs that we determined did not involve any copyright fees; their prices averaged 14.7 cents per page.

Applying these unit costs to the pages of required readings posted to e-reserves in the two surveyed courses, we arrived at a range of prices that students in these courses could reasonably expect that a coursepack with all the required readings (but not the exams, study notes and extra materials), had one been produced, would have cost them (Section II of Table 4).

For the 35 respondents (34.6% of the total sample) who reported reading only online and printing none of the required readings, their costs incurred are essentially zero, making obvious the cost-effectiveness of their use of online resources (not withstanding the university's presumably minor costs of maintaining the IUB e-reserve system). For the 66 respondents who printed at least some materials, the median calculated number of pages printed is shown on line III.a. Since the great majority of students who reported printing any e-reserve pages said that they did so using university printers subject to the $.04 per page print quota overage charge, we take that amount to be the respondents' effective direct cost per page, resulting in median direct costs reported on line III.c. To estimate respondent time costs, we asked students to report the average amount of time per week that they had spent in printing and binding e-reserve materials for the surveyed class. Twenty-seven and three-tenths percent of all respondents (21.7% in the Telecom class, 40.0% Biology) said that they bound at least some of the readings themselves, but only 3.0% that they paid to have them bound at a commercial establishment. We also asked if they held a paid job during the semester, and if so, the average wage they earned from that work. A total of 43.6% reported that they were employed. Following the standard practice in cost–benefit studies, the average wage of this group is taken to represent the median respondent's opportunity cost of time spent printing and binding e-reserve materials. Using these data, we calculated costs per semester for the median student who printed, and applied that to the median wage earned in part time work ($8.00 for both classes), to estimate total time costs to the median respondent (line III.e.) Comparable printing and time costs of the 8 students (4 in the Telecom course and 4 in the Biology course) who said that they printed off the entire collection of required readings (and who also supplied information on the amount of time it took them to print and bind) are reported on line IV.e. of Table 4.

Table 4
Cost comparisons based on medians.

	Items	Telecom class	Biology class
I.	Pages of required e-reserve reading	567	217
II.	Estimated cost of complete coursepacks		
	a. Without copyright fees (@14.7 cents)	$83.48	$31.95
	b. With copyright fees (@26.4 cents)	$149.54	$57.23
III.	Student printing/binding costs (among all printers)		
	a. Median pages printed	248.1	108.5
	b. Median time spent per semester (min / week × 15)	262.5	75.0
	c. Direct printing expenses (@ $.04) per person	9.92	4.34
	d. Median time costs (@ $8)	$35.00	$10.00
	e. Median total costs	$44.92	$14.34
IV.	Student printing/binding costs (complete packet printers only)		
	a. Median pages printed	567	217
	b. Median time spent per semester (min / week × 15)	300.0	45.0
	c. Direct printing expenses (@ $.04)	$22.68	$8.68
	d. Median time costs (@ $8)	$40.00	$6.00
	e. Median total costs	$62.68	$14.68
V.	Reported willingness to pay for complete packet (full sample)		
	a. Median	$30.00	$25.00
	b. Mean	$35.80	$28.50

Overall, these data suggest that even when time costs are considered, the median student who printed at least some e-reserves incurred considerably less total cost than a full coursepack sold via the bookstore would have been priced, even if no copyright fees were incurred. Similarly for full packet printers, although to be expected, the comparisons in this case are less extreme. Finally, it can be questioned whether students actually value their time printing and binding as much as their hourly wage (or wage opportunity). As shown in Table 4, direct money costs alone (lines III.c. and IV.c.) are relatively very minor compared to estimated printed packet costs.

While there was considerable variance around the median values, analysis on an individual respondent level provides a more precise answer to our research question about the cost-efficiency of e-reserves vs. printed resources. Of respondents in the Telecom and Biology classes, 17.4% and 35.0% respectively, reported that they incurred combined money plus time costs (the latter evaluated at the median wage level of $8) greater than the projected coursepack price without copyright fees. Comparable percentages for the packet without copyright fees were only 8.7% and 25.0%, respectively. That is, e-reserves were more cost effective than the purchase of a coursepack for large majorities of respondents in both courses. For an additional benchmark, we asked all student respondents to indicate the maximum amount they would be willing to pay (WTP) for a printed and bound coursepack that would include all of the required course readings, had only such a coursepack been available in the absence of any electronically supplied readings. The median and mean amounts are shown in Section V of Table 4, indicating in both classes a WTP well below the projected actual packet costs.

On an individual respondent level, 7.9% and 28.0% respectively, of the 76 Telecom and 25 Biology class respondents indicated a WTP greater than the packet costs without copyright fees. Comparable percentages for the packet with copyright fees were extremely low: 0% and 4.0%, respectively. For an even greater proportion of respondents, that is, e-reserves were a more cost-effective alternative than a coursepack when based on WTP.

More generally, these comparisons remain broad and necessarily hypothetical. It is likely, for example, that if a hardcopy coursepack were produced as an alternative, a cost-conscious instructor might include fewer pages of readings. Since a relatively high proportion of students enrolled in a course do buy a coursepack when it is the only source of required readings, the reported WTP amounts are also likely to understate actual willingness to pay. It is nevertheless evident from our study that a shift from printed to free-of-charge electronic resources is not in fact "free" in economic terms, as often assumed, because many students incur costs for at least a partial re-creation of a comparable printed set of readings. Moreover, for at least the roughly three quarters of printing students in our survey who did no binding of their own or did not pay for a commercial binding service, the resulting stack of paper is likely to be less desirable than a professionally printed and bound reading packet. Overall, however, it is clear from our results that most students incur considerably lower total costs (direct + time), and dramatically lower direct costs alone, than they would incur by buying a printed packet from a bookstore. Thus, other things being equal, a system of freely accessible electronic readings appears to be a cost-effective and thus economic welfare enhancing alternative to printed resources for the great majority of students in our sample.

Table 5
Preference for electronic resources vs. hardcopy by selected questionnaire variables: All respondents.

Variables	Prefer electronic resources (56.4%)	Prefer hardcopy (46.6%)	Statistical significance of difference[a]
ORI	10.73	18.69	$t\,(99) = -0.64$
%Read/will read online	42.70	50.17	$t\,(99) = -1.05$
% Printed/will print	34.83	34.13	$t\,(99) = 0.10$
Word processing proficiency	4.70	4.61	$t\,(99) = 0.66$
Excel proficiency	3.53	3.73	$t\,(99) = -0.85$
Adobe proficiency	3.37	3.59	$t\,(99) = -0.94$
HTML proficiency	2.70	3.05	$t\,(99) = -1.25$
Computer proficiency index	3.58	3.74	$t\,(99) = -1.10$
GPA	3.32	3.28	$t\,(99) = 0.42$
Hours of study per week	14.32	18.17	$t\,(99) = -1.85^{*}$
Age	20.86	21.70	$t\,(99) = -1.88^{*}$
Gender: Male %	42.10	59.10	$\chi^2\,(1) = 2.87^{*}$
School level	3.07	3.39	$t\,(99) = -1.99^{**}$
Laptop ownership/access: %	97.96	94.10	$\chi^2\,(1) = 1.63$
Base	57	44	N = 101

* $p < .1$.
** $p < .05$.
*** $p < .01$.
[a] Chi-square rather than t tests are required for "Gender" and "Laptop ownership/access" since these are categorical variables.

4.3. Preferences and perceived advantages: E-reserves vs. printed readings

In addition to specific questions about their behavior as students in the surveyed courses, all respondents were asked near the end of the survey: "Overall, do you generally prefer to have the instructor assign published books or other hardcopy resources, or to have the same readings in the form of electronic resources?" Answers were in favor of electronic readings: 56.4% vs. 43.6% for print. These preferences did not differ significantly for the 2 courses: 57.9% v. 52.0% respective preferences for electronic readings in Telecom and Biology; $t(99) = 0.51$, $p = .61$. As shown in Table 5, respondents who preferred electronically accessed readings were (marginally) significantly more likely to be female (χ^2 (1, N = 101) = 2.87, $p < .1$), be younger ($t(99) = -1.88$, $p < .1$), be at a lower grade level ($t(99) = -1.99$, $p < .05$), and to study for fewer hours ($t(99) = -1.85$, $p < .1$), although most of these associations were relatively weak. Notably, however, preferences for electronically supplied readings had no statistically significant relationship to the online reading intensity index (ORI), or to the related measures of online reading or printing behavior.

More striking were the answers respondents selected from a given list of potential advantages of printed vs. electronically accessed readings. There were 2 successive questions. The first: "In general, what advantages of published textbooks, coursepacks, or other printed course materials do you see? (please indicate all that apply)" with the seven choices shown in Table 6. The second question was "In general what advantages of e-reserves or other electronic resources do you see? (please indicate all that apply)," and presented the identical choices.

As shown in Table 6, respondents overwhelmingly reported that electronically supplied readings had a cost advantage. On every other criterion, however, students gave the advantage to printed resources, in most cases by wide margins. Of particular interest, respondents reported by decisive margins that they "usually end up reading more of the assigned readings" and "usually end up learning more from the assigned readings" when readings were supplied in print. As also shown, the pattern of these answers was similar for the two courses.

5. Discussion and conclusions

In surveys of two undergraduate courses, we found that by page volume, nearly half of electronically supplied required readings were read online, and about one-third were printed off. About 2/3 of respondents printed at least some readings. Although we cannot make statistical comparisons over time due to differing methodologies, the pattern of substantial printing for later reading is generally consistent with results of previous studies (Austin & Taylor, 2007a; Chang and Ley, 2006; Vernon, 2006). Our measurement of student costs incurred in printing and binding activities indicates that significant resources, in time and money costs, were expended in self-converting electronically accessed readings back to printed form Overall, however, we found that free-of-charge electronic readings were clearly cost-effective for the great majority of surveyed students in comparison to what an equivalent printed coursepack with all the required readings would have cost them, as well as to their stated willingness to pay for such a coursepack. These results generally confirm the conventional wisdom that freely available electronically accessed readings are cost effective for students, and do not support Besen's (1986) and Besen and Kirby's (1989) theoretical conclusion that printing behavior may be socially inefficient.

The findings of our study depart in one respect from most previous studies in that we find a majority of students to state a slight preference for electronically supplied readings instead of those supplied in printed form—at least when they are supplied free of charge. We also found this

Table 6
Perceived advantages of printed materials vs. e-reserves/electronic resources*.

Perceived advantages	Adv. of printed materials (% Yes)			Adv. of e-reserves/electronic resources (% Yes)		
	Telecom	Biology	Combined	Telecom	Biology	Combined
Cost	6.6	8.0	6.9	96.1	96.0	96.0
Portability	52.6	60.0	54.5	55.3	40.0	51.5
Ease of reading	65.8	80.0	69.3	19.7	12.0	17.8
Ease of highlighting or making notes while reading	81.6	80.0	81.2	10.5	12.0	10.9
Ease of studying for exams	63.2	72.0	65.3	21.1	28.0	22.8
I usually end up reading more of the assigned readings	47.4	32.0	43.6	15.8	24.0	17.8
I usually end up learning more from the assigned readings	34.2	40.0	35.6	6.6	28.0	11.9

* See Appendix A for the specific questions on which the data in this table are based.

preference, however, to be overwhelmingly attributable to the perceived cost advantage of electronic access. Large majorities report that they generally study more and learn more when printed readings are supplied. In this respect, our study is consistent with findings of many previous authors in both face-to-face and online learning environments that students prefer to use printed readings (e.g., Daniel & Woody, 2013; Precel et al., 2009; Spencer, 2006, and findings of experimental studies that reading print leads to better learning outcomes (Ackerman & Goldsmith, 2011)).

Our study has evident shortcomings. Two courses, of course, cannot be generalized to the general undergraduate population. Our survey responses also relied heavily on student self-reports about recollections of their past printing and reading behavior during the semester, and also about their anticipated printing and reading behavior until the end of the course. Potential bias of willingness-to-pay measures is also well known. It seems unlikely, however, that the relatively decisive overall findings of our cost-effectiveness analysis, and our interpretation of those findings, would be affected by inaccuracies or bias in our survey data that result from these causes.

An important question raised by our study is whether overall student preferences to have freely available electronically accessed readings are properly aligned with the objectives of university-level teaching institutions to provide high quality learning outcomes; as our survey results suggest, students decisively report a belief that their learning outcomes are better served by readings that are supplied in printed form. Of course, students have the option of converting electronically accessed readings to print at relatively low cost, and as our study shows, many students do that. Remarkably, however, our survey found (Table 5) that respondents who said they preferred readings to be supplied in printed form were no more likely to print off the electronic readings themselves than those who said they preferred readings to be supplied electronically. These apparently paradoxical results thus suggest that, at least given the current state of technology, self-printing/binding activity by students may fall short as a natural "escape valve" for students who are supplied with electronic readings, but believe that they learn more from using print. Students, that is, are naturally driven to seek low cost reading resources, but our results suggest that their learning outcomes may be poorly served in the process.

This interpretation echoes concerns that were expressed in the Canadian national college student survey (Rogers et al., 2011) about the rapid movement in higher education toward e-learning course components, including electronic readings. Although as noted above, over 80% of respondents said in that survey that they preferred to use hard copy readings, 44.2% also said that in the future they would like to see more "electronic versions of course readings/books" while only 15.3% said they would prefer to see less (Rogers et al., 2011, p. 15). Our results suggest that the reason for this contrast (which the study's authors describe as "somewhat puzzling") may be the perceived cost—but not the learning—advantages of electronically supplied readings.

As on-screen presentation continues to improve, and higher quality end-user devices for reading, note taking, etc. proliferate, it seems certain that the usability balance, as well as the cost balance, will continue to shift in favor of electronic supply and on-screen reading. Future research should continue to monitor the shifting balance between on-screen vs. print reading usability—and especially how those shifts are affecting learning outcomes. Our understanding of how learning may take place differently for on-screen vs. print readers, and how on-screen learning experiences can be better designed, is a high research priority. Obviously, the growing flood of digital natives into our education system makes online reading a very familiar practice. But as suggested by the finding of Daniel and Woody (2013) that at-home student research subjects both took more time to read e-text materials and engaged in more multi-tasking, students' use of online resources for information and entertainment in their daily lives is not necessarily good training for using electronic readings to study and learn.

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Appendix A. Survey questions underlying text in Tables 2 and 6

Online reading vs. printing/print reading (Table 2)	
(4a) Please estimate, in terms of page volume, the percentage of the required e-reserve/Oncourse electronic resources readings ASSIGNED TO DATE that you have:	Printed onto paper (%) Not printed onto paper (%)
(4b) Now taking the required e-reserve/ Oncourse electronic resources readings that you have printed onto paper as the base, please estimate, in terms of page volume, the percentages of these printed off readings that you have: (*asked of all respondents who reported in (4a) that they had "printed onto paper" > 0%*)	Already read (%) Not read, but probably will read before the end of semester (%) Not read, and probably will not read (%)
(5) Taking the required e-reserve/ Oncourse electronic resources readings for this course that YOU HAVE NOT PRINTED ONTO PAPER AS THE BASE, please estimate, in terms of page volume, the percentage of these readings that you have: (*asked of all respondents who reported in (4a) that they had "not printed onto paper" > 0%*)	Read online (%) Not read but probably will read online before the end of the semester (%) Not read but probably will print onto paper and then read before the end of the semester (%) Not read and probably will neither print onto paper nor read online (%)

Perceived advantages of printed vs. electronically supplied readings (Table 6)	
(18) In general, what advantages of published textbooks, course packs, or other printed course materials do you see? (please indicate all that apply)	Cost Portability Ease of reading Ease of highlighting or making notes while reading Ease of studying for exams I usually end up reading more of the assigned readings. I usually end up learning more from the assigned readings.
(19) In general, what advantages of e-reserves or other electronic resources do you see? (please indicate all that apply)	Cost Portability Ease of reading Ease of highlighting or making notes while reading Ease of studying for exams I usually end up reading more of the assigned readings. I usually end up learning more from the assigned readings.

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