Title
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Journal
Computers & Education, 59(4)

ISSN
03601315

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Publication Date
2012-12-01

DOI
10.1016/j.compedu.2012.05.002

Peer reviewed

Computers & Education 59 (2012) 1300–1308

Contents lists available at SciVerse ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

The impact of laptop-free zones on student performance and attitudes in large lectures

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ARTICLE INFO

Article history:
Received 13 January 2012
Received in revised form
1 May 2012
Accepted 4 May 2012

Keywords:
Human–computer interface
Improving classroom teaching
Pedagogical issues
Public spaces and computing

ABSTRACT

The goal of this study was to determine if laptop use in lecture negatively impacts learning outcomes of surrounding students taking notes on paper. Two sections of a large introductory biology course (>400 students/section) were zoned into a laptop-permitted and a laptop-free area. Two sections in which laptop users could sit anywhere served as the Control. There was no difference in the attendance (~85%) or percentage of students using laptops (~29%) between Zoned and Control sections. Academic performance, based on exam points earned, was not significantly different for paper users in Zoned and Control sections indicating laptop use did not impair the overall achievement of surrounding students. However, there was a correlation between exam performance and note taking preference: paper note takers scored significantly higher and laptop users scored significantly lower than predicted by pre-class academic indicators ($p < 0.01$, paired t-test). The majority of both laptop (64%) and paper users (82%) in the Zoned sections supported a policy restricting laptop use to specific areas. Thus, while we further investigate whether the relationship between laptop use and performance is correlative or causative, zoning is an effective method for accommodating both laptop users and paper note takers in the same lecture hall.

1. Introduction

Instructors in large lecture halls have been competing for their student's attention in the face of a wide variety of distractions for many years (Appleby, 1990). Some off-task activities, such as completing assignments for other classes, generally impact only the student who chooses to engage in this behavior. In contrast, other activities, including chatting with a neighbor or passing notes, have the potential to reduce the ability of surrounding students to focus on the class. There has been a proliferation of laptops in lecture halls over the past 5 years. While most students bring laptops to class with the intention of using them to take notes, laptops also provide tempting ports of entry to a vast digital universe. In a typical lecture hall a bright screen filled with Facebook or YouTube is visible to a large number of students. This has dramatically increased the ability of one student to unintentionally negatively impact the learning environment of their neighbors (Granberg & Witte, 2005; Yamamoto, 2007).

One strategy for eliminating distractions associated with laptops, both for users and the surrounding students, is to ban laptops in the classroom (Fried, 2008; Yamamoto, 2007; Young, 2006). In one report this approach led to increased satisfaction of both the instructor and students when the laptop ban was combined with an increase in strategies to actively engage students in class (Maxwell, 2007). Generally however, students oppose bans on classroom use of laptops. Some faculty also support unrestricted use of laptops asserting that students should be allowed to weigh the costs and benefits of using their laptop for non-class related activity (Brady, 2009; Young, 2006). Other instructors, even some who believe banning laptops would be beneficial, allow unrestricted laptop use in their classes to avoid student backlash (Glenn, 2010).

Is there an acceptable compromise between a complete ban and unrestricted use? One strategy has been to create "Laptop-free zones" in the classroom to accommodate paper-users who are annoyed, dismayed and distracted by their peers who "doodle via Google" (Brady, 2009; McCreary, 2008). Student satisfaction with the arrangement was reported to be high but there were no data regarding the impact

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doi:10.1016/j.compedu.2012.05.002

of the arrangement on student performance. Several studies have demonstrated a negative correlation between multitasking on laptops and student performance (Fried, 2008; Grace-Martin & Gay, 2001; Hembrooke & Gay, 2003). We are not aware of any studies that have directly addressed the effect of laptop use on the performance of surrounding students, however some have documented the extent to which laptops distract surrounding students. In Fried (2008) students reported that other students' computer use was the greatest distraction during lecture. In a second study, the two most often cited reasons for distraction were curiosity about what is on a neighbors screen and the sound of the keyboard tapping (Borbone, 2009).

In this study, we tested the impact of "laptop-free zones" on student learning and attitudes in large lecture sections of introductory biology at a public research university. Two sections were designated as Control, with no restrictions on where laptop users could sit. Two sections were designated as Zoned, where laptop users were permitted only in designated areas within the lecture hall. In-class observations, exam performance data, and responses to an anonymous attitude survey were used to:

1) Compare patterns of laptop use in Control and Zoned sections
2) Determine if use of laptops impacts the performance of surrounding students who take notes on paper
3) Compare student attitudes about laptop use and zoning in Control and Zoned sections

2. Methods

2.1. Participants

The subjects for this study were students in four sections (A-12pm, B-1pm, C-8am and D-4pm) of "Bio 93: DNA to Organisms" at the University of California, Irvine in Fall 2010. All four sections met 3 days a week (MWF) for 50 min Sections A and B were team taught by one faculty pair, and Sections C and D were team taught by a second faculty pair. Students enrolled in sections based on individual scheduling preferences. All student identifiers (e.g. names and UCI student ID numbers) from iClicker data and exam performance data were replaced with 5-digit random ID numbers in accordance with an IRB approved protocol and FERPA guidelines. Opt out instructions were explained on the first day of class by a member of the research team.

Sections A and C were pooled together as the Control, and sections B and D were pooled together as Zoned. Students who opted out, had a FERPA hold on their roster entry, were under 18, enrolled as Pass/No Pass, or failed to appear for their final exam were excluded from the analyses (78 students out of a possible 1743 were excluded). Demographic data were collected from the Registrar after final grades were submitted. The Control and Zoned sections were similar with the exception of small differences in the percentage of biology majors (Fisher's Exact Test; $p < 0.005$) and percentage of females (Table 1; Fisher's Exact Test; $p < 0.005$). There were no differences between the Control and Zoned sections in three pre-class academic indicators: a first day concept assessment quiz (Shi et al., 2010), composite SAT scores, and the number of students with scores of 3 or higher on the AP Biology exam (Table 1).

2.2. Lecture hall organization

In the Control classes there were no restrictions on where laptop-users could sit. In the Zoned classes laptop users were seated in a specific region which still allowed all students equal opportunities to sit at the back or front of the lecture hall (Fig. 1).

On the first day of class faculty briefly addressed note taking in Bio 93 and covered the following points:

- Different students have different styles of learning and taking notes in lecture.
- Power point slides are available for download from website prior to lecture.
- Paper note takers: bring printouts of slides or notebook paper.
- Laptop note takers: do not use laptops for non-class activities.

The two Zoned classes were also told:

- Past students who take notes on paper have indicated they are often distracted by laptops.

Table 1
Demographics and preclass academic indicators of students in four sections of Bio 93 "DNA to Organism" in Fall 2010. All data was provided by the UCI Registrar. * = significant differences between Control and Zoned (Fisher's exact test; $p < 0.005$). SAT and concept assessment scores are mean ± 1 SE.

	Control	Zoned
Total # of students	822	843
% Biology majors*	64.8	57.1
% Freshman	86.1	84.22
% Female*	66.9	61.0
Ethnicity		
% Asian/Pacific Islander	63.9	63.2
% White/Caucasian	17.9	16.1
% Underrepresented minority	14.1	15.9
% Decline to state/other	4.1	4.7
Academic indices		
Composite SAT	1770 ± 7	1760 ± 7
# with biology AP ≥ 3	252	255
Pre-class concept assessment	14.2 ± 0.2	14.2 ± 0.2

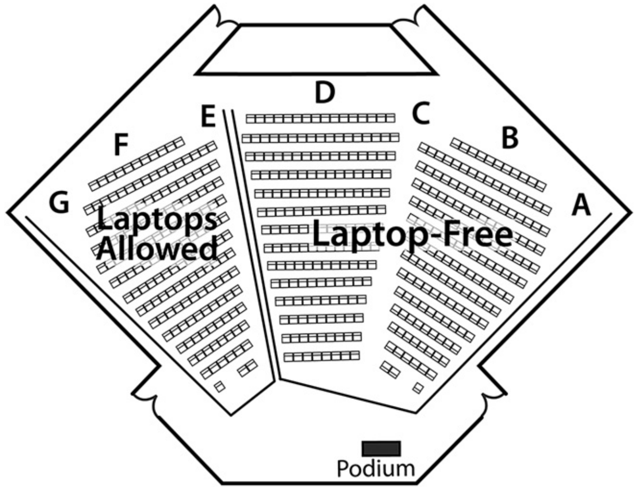

Fig. 1. Illustration of the lecture hall used for teaching all four sections. In the Zoned classes, two-thirds of the lecture hall were designated as laptop-free and the remainder was designated as laptops allowed. Letters A–G correspond to the seven locations observer stood while monitoring computer use.

- To accommodate both laptop and non-laptop users, we will have a laptop use and a laptop free zone in the class room.
- Zones will be adjusted in size to accommodate everyone's preference.
- Starting next class we ask you to sit in the appropriate zone.

In the second class meeting of the Zoned sections, a zoning slide was up when students entered the lecture hall and TAs asked those who sat in the wrong section to move before class started. During the rest of the quarter neither the instructors nor the teaching assistants interfered with student laptop behavior except for a small number of occasions when a student was asked to move when using a laptop in a laptop-free zone.

2.3. In-class laptop use

Observations were made from 7 different locations at the back of the lecture hall (Letters A through G; Fig. 1). Selecting spots for observation was a compromise between selecting random locations and not disrupting lecture or blocking student view of the presentation. Standing at the top of the lecture hall it was possible to view the contents of most laptop screens from the first to the last row. In all four sections the PowerPoint slides for every lecture were available for download from the course web page. When viewed on a laptop, PowerPoint slides were very distinct and easily recognized. Similarly, most non-course related content such as webpages and games were easily recognized from a distance by their headers, color schemes and graphics. For Word or other text documents, it was sometimes difficult to distinguish class notes from homework for another class. If the content of a laptop screen could not be scored as on- or off-task it was not counted.

Observations were made by NMA on 13 separate days, spread throughout the quarter in each of the 4 sections. Observations included a manual count of the number of laptops in each section of the lecture hall. This was started 5 min after class started and ended 3–5 min before the end of lecture. Observations of laptop use were approximately 2 min in duration, occurring at 2–5 min intervals through out the class. During each observation the following information was recorded for visible laptop screens on a data collection sheet: number of laptops with PPT lecture slides on the screen, the number with lecture notes in a word processing or note taking program, and the number with content not related to the class. The total number of laptops visible during a single observation varied between 4 and 45, depending on the class and the observation location.

Self-reported note taking preference was obtained from the following question on the midterm and final exam:

What is your primary method of taking notes in this class? (not graded; 0 points)

a. Handwritten on printouts of the PowerPoint slides
b. Handwritten on notepaper
c. Typed on a laptop directly into PowerPoint
d. Typed on a laptop using other software (e.g. Word, OneNote)
e. I rarely took notes

The question, clearly marked on the exam as not graded, was answered by 96% of the students on the midterm and 92% of the students on the final. The final exam version also included space for students to leave comments if desired.

2.4. Exam performance data

The distribution of points for homework, quizzes and discussion section differed between the four lecture sections. In addition, different faculty wrote the midterm and final exams, and each section received a different version. Therefore, student performance was based on exam points earned from the midterm and final exam within each section. To evaluate the relationship between note taking strategy and performance across multiple sections in which there were variations in both mean exam grade and distribution of scores, the exam scores were normalized within each section as Z-scores using the following calculation:

$$Z - score = (X_C - X_s)/SD$$

where X_c is the class mean, X_s is the student score, and SD is the class standard deviation. Plus or minus one Z-score is equivalent to ± 1 standard deviation from the class mean.

We also calculated a predicted Z-score based on previous studies showing that a variety of factors are predictive of student performance (Freeman et al., 2007). We evaluated 7 factors: Math SAT, Verbal SAT, Composite SAT Score, AP Biology Score, Year of Matriculation, Gender, Ethnicity and Pre-class Concept Assessment Score. Five variables (Table 2) were found to be significant using a backward elimination of variables technique (Freeman et al., 2007; Zar, 2010). Gender was entered into the model as a binary variable with 0 = Female and 1 = Male. The linear combination of these variables was significantly related to class performance (Table 2; $F_{(5,1659)} = 152.76$; $p < 0.0001$, $r^2 = 0.315$). The significance of the regression coefficient, β for each variable was tested with a Student's-*t* (Zar, 2010). Student's *t*-values and significance, *p*, for each β are shown in Table 2. This multiple regression model was used to predict Z-scores of the students ($n = 1665$).

2.5. Anonymous surveys

Students were asked to complete an anonymous on-line survey at the end of the quarter after final grades were submitted. Surveys were distributed to students based on the section in which they were registered. This allowed us to match survey responses to the correct section but maintain anonymity. Response rate was 44% in Control and 38% in the Zoned sections.

2.6. Statistical analysis

Data that followed a normal distribution were analyzed with standard *t*-tests. Categorical data were analyzed with Fisher's exact test for 2×2 comparisons and a Chi-square test for larger data tables. InStat v3.1 (GraphPad Software) was used for all analyses.

3. Results

3.1. Laptop use in Control and Zoned classes

The percent attendance each day was defined as the number students who responded to at least one in-class question using their iClicker divided by the number of students registered for that section. The number of students using laptops was counted manually. The percentage of students who attended lecture and the percentage who elected to use laptops were relatively constant over the course of the quarter in both Control and Zoned sections (Fig. 2A). There was no overall difference in average attendance in the Control (85.4 ± 1.4%, mean ± SEM) and Zoned (85.5 ± 1.4%, mean ± SEM) sections (*t*-test; $t(54) = 0.026$; $p = 0.97$ (two-tailed)). Nor was there a difference in the percentage of laptop users in Control (29.5 ± 1.0%, mean ± SEM) and Zoned (28.4 ± 0.8%, mean ± SEM) sections (*t*-test; $t(28) = 0.828$; $p = 0.41$ (two-tailed)).

The percentage of laptop users that were off-task during a single observation was defined as the number of laptops that were displaying non-course content divided by the total number of visible laptops. A wide variety of off-task activities were observed but the use of social networking sites (primarily Facebook, IM and video chat) was the most common in both Zoned and Control sections. Over 60% of the observations included at least one laptop user engaged in social networking. The percentage of laptops displaying non-course related content was significantly higher in the Zoned (24.0 ± 0.73%, mean ± SEM) than Control (16.0 ± 0.62%; mean ± SEM) sections (Fig. 2B; *t*-test; $t(28) = 5.34$; $p < 0.0001$(two-tailed)). These data indicate that while zoning did not affect the probability a student would attend class or elect to use a laptop, the laptop users in Zoned sections were more likely to be off-task.

In both Control and Zoned sections students self-reported their note taking preference by answering a multiple choice question on this topic on the midterm and again on the final exam. Approximately 50% of the students consistently reported they took notes on paper on both the midterm and final exams, and ~22% of the students consistently reported using laptops in class (Fig. 3A). The remainder used a mix of methods or left the answer blank on the midterm and/or final. These students were excluded from further analyses of in-class performance data. The distribution of note taking preferences was not significantly different between the Control and Zoned sections (Fig. 3A; $\chi^2(2, 1665) = 0.3485$; $p = 0.8401$). These self-reported data were consistent with the data collected during classroom observations.

Some of the students ($n = 298$) also provided comments in the free-response section of the final exam about why they chose to take notes on laptop, paper, or other. These were coded into 3 categories: easy/convenient, facilitates learning, and other. For paper note takers, "facilitates learning" was the primary reason for using paper (Fig. 3B). In contrast, convenience was the primary reason given by students using laptops (Fig. 3B). The distribution of responses was significantly different between the paper users and the laptop users ($\chi^2(2, 298) = 20.23$; $p < 0.0001$).

Table 2
The influence of predictor variables on exam performance (predicted Z-scores).

Predictor variable	β	Standardized β	*t*	*p*
Constant	−214.1466			
AP biology score	0.1622	0.302	13.327	<0.0001
Math SAT	0.0029	0.230	9.124	<0.0001
Verbal SAT	0.0019	0.141	5.659	<0.0001
Gender	0.1755	0.084	4.066	0.0001
Year of matriculation	0.1050	0.063	3.069	0.0022

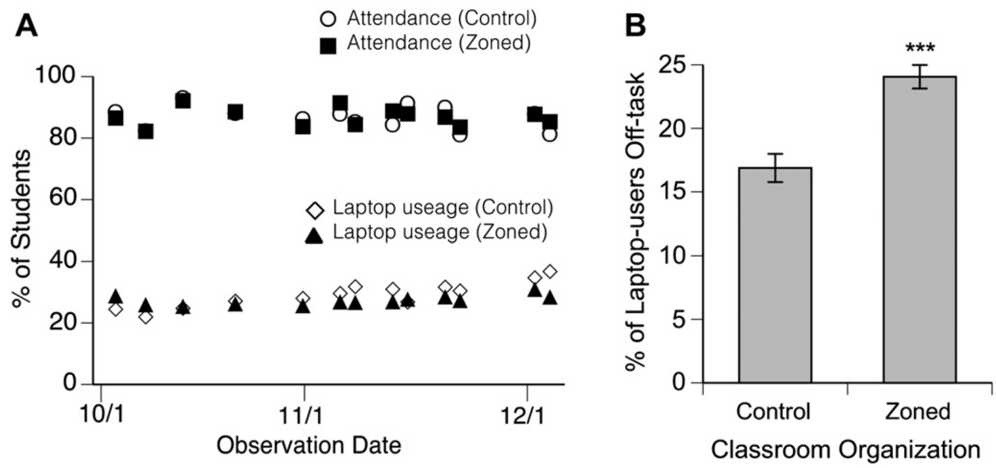

Fig. 2. A) The percentage of students who attended lecture and the percentage of the attending students who elected to use laptops on 13 observation dates throughout the 10 week quarter were similar in the Control and Zoned sections. B) Average percentage of laptop users off-task at any one time was significantly higher in the Zoned versus Control sections (*** = $p < 0.0001$).

3.2. Exam performance of paper note takers and laptop users

To determine if use of laptops in class negatively impacts learning outcomes of surrounding students who took notes on paper, we compared the exam scores of paper users in Zoned and Control sections. To normalize data across sections, total exam scores were converted into Z-scores and a multiple regression model was used to calculate the predicted Z-score for each student based on academic indices and demographics (as detailed in methods). The Actual Z-score minus the Predicted Z-score for each student was calculated and these values allowed comparison of performance between students with different backgrounds and in different sections.

The Actual minus Predicted Z-scores for paper users in the Control and Zoned sections were not significantly different (Fig. 4; *t*-test; $t(834) = 0.6676$; $p = 0.5046$ (two-tailed)). Thus, use of laptops in class does not appear to negatively impact the learning outcomes of surrounding students who elect to take notes on paper. In addition, clustering of laptops did not negatively impact laptop user performance since there was no difference in the Actual minus Predicted Z-scores for the laptop users in the Control versus the Zoned sections (Fig. 4; *t*-test; $t(371) = 1.407$; $p = 0.1604$ (two-tailed)).

Interestingly, the Actual minus Predicted Z-scores were positive for the paper users and negative for the laptop users in both Control and Zoned sections. To further examine whether there may be a correlation between note taking preference and exam performance the Actual Z-scores were compared to the Predicted Z-scores for all paper users versus all laptop users, regardless of zoning. For paper users the Actual Z-scores were significantly higher than Predicted (Fig. 5A; paired *t*-test; $t(834) = 3.249$; $p = 0.0012$ (two-tailed)). In contrast, for laptop users the Actual Z-scores were significantly lower than Predicted (Fig. 5A; paired *t*-test; $t(371) = 2.727$; $p = 0.0067$ (two-tailed)).

The average difference between Actual and Predicted Z-score corresponds to approximately 3% of the available exam points. Although this represents a relatively small number of points it was sufficient to impact the distribution of final grades. The percentage of paper users who received As was significantly higher than for laptop users (Fig. 5B; Fisher's Exact Test; $p < 0.05$). The difference between paper and laptop users who received a D or F was not significant (Fig. 5B; Fisher's Exact Test; $p > 0.05$). We do not, however, have information that addresses whether there was a causative relationship between laptop use and performance.

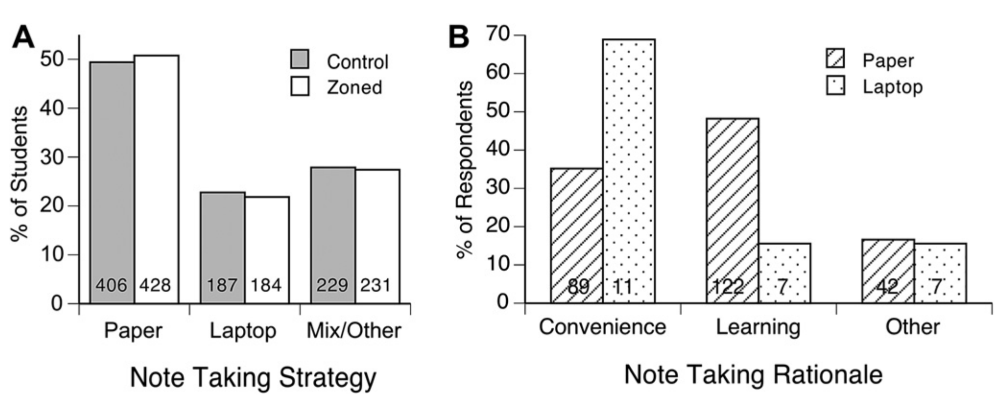

Fig. 3. A) Note taking strategy did not vary significantly between the Control and Zoned classes ($p > 0.05$). Students were identified as paper and laptop users if they indicated they used the same note taking strategy on the midterm and the final exam question on this topic. Students who indicated different note taking strategies on the midterm and final exam questions, or chose other as there note taking strategy were defined as "Mix/Other" and were excluded from further analysis. B) Some students (298/1665) also provided comments about why they chose their note-taking strategy. These responses were coded into 3 categories: easy/convenient, facilitates learning, and other. The distribution of reasons is significantly different between paper and laptop users ($p < 0.0001$). Numbers indicate sample sizes for each group.

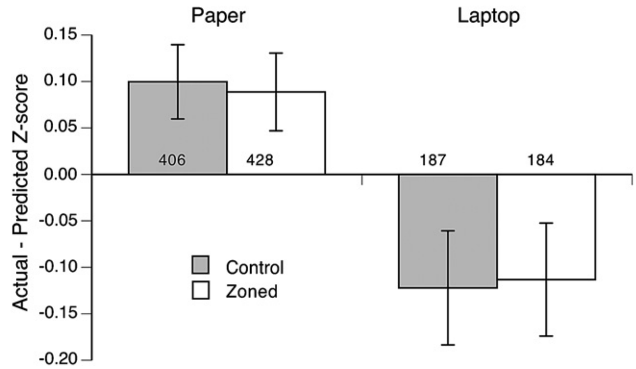

Fig. 4. Zoning did not have a significant impact on performance of paper or laptop users. For each student, their Predicted Z-score was subtracted from their Actual Z-score. The Actual-Predicted Z-scores in Control and Zone sections were not significantly different for either the Paper users or the Laptop users ($p > 0.05$). Numbers indicate sample sizes for each group (mean ± 1 SE).

3.3. Student attitudes about zoning policy

To explore student attitudes about the zoning policy several questions on these topics were included on an anonymous on-line survey that students were asked to voluntarily complete after final grades were submitted. Completion rate was similar in Control (43%) and Zoned (38%) sections. Less than 10% of the students supported banning laptops from the lecture and there was no difference between paper and laptop users in Control or Zoned sections (Fig. 6A; Fisher's Exact Test; $p > 0.05$). When asked if they supported restriction of laptop use to designated areas less than 50% of the paper note takers in the Control classes agreed compared to 82% in the Zoned classes. Not surprisingly only 21% of laptop users in Control classes agreed with restricting laptops to designated areas but unexpectedly, 64% of laptop users in Zoned classrooms also agreed with this policy. (Fig. 6B; Fisher's Exact Test; $p < 0.05$). These data indicate that before students have actually experienced a zoned class they are more likely to express opposition to a policy that restricts laptop use to specific areas. After exposure to zoning the preference of both paper users and laptop users shifts significantly in favor of zoning.

4. Discussion

4.1. Effect of zoning on laptop use during class

Our observational data indicate that the average percentage of laptops off-task at one time during lecture in Control classrooms was 17%. This is lower than expected based on previous studies in which a high percentage of students self-reported engaging in off-task behavior during class. For example, over 70% of law students self-reported using laptops for non-class activities during lecture (McCreary, 2008). In a second study 90% of undergraduates reported they checked email during class (Borbone, 2009). However, these self-reported student data do not give any indication about the percentage of laptop users that could be off-task at a single time point during lecture. Our assumption that we would observe a high percentage of students off-task at one time was also influenced by two studies in which computer use was directly monitored with a proxy server or spyware. In one study some students spent more than 50% of class time off-task (Hembrooke & Gay, 2003), and in the second, some students viewed off-task windows seven times more than on-task windows (Kraushaar & Novak, 2010). An important distinction between the aforementioned studies and our work is that we evaluated the aggregate behavior of students at various time points during class, rather than individual activity. Thus the relatively low off-task behavior we observed reflects laptop users going off-task only intermittently. Additionally, it seems likely that specific class demographics also affect off-task computer use. The

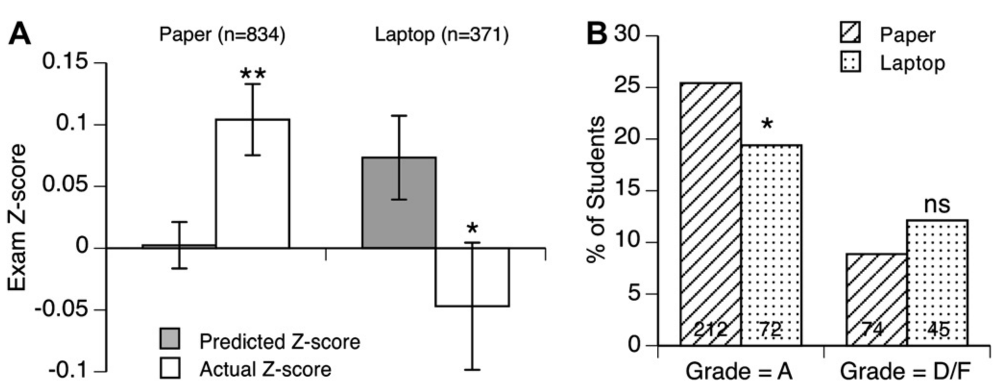

Fig. 5. Performance difference between paper and laptop users. A) There were significant differences between Predicted and Actual Z-scores for both paper users and laptop users. Paper users scored significantly higher, and laptop users significantly lower, than predicted. Numbers indicate samples sizes for each bar (mean ± 1 SE). B) Significantly more paper users received an A in the course, than laptop users. There were no differences in the distribution of D/F grades. (** = $p < 0.01$; * = $p < 0.05$; ns = not significant).

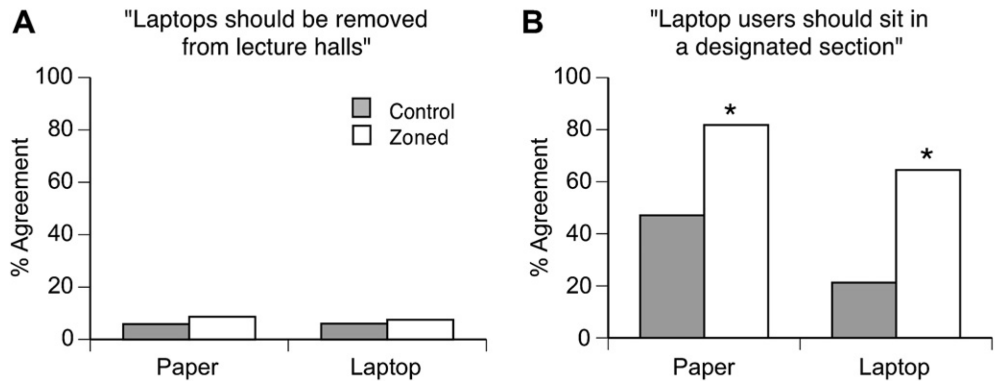

Fig. 6. A) In a post-class survey less than 10% of students agreed with the statement "Laptops should be removed from lecture halls", regardless of their notetaking preference or zoning. B) Agreement with the statement "Laptop users should sit in a designated section" was significantly higher in Zoned compared to Control classes for both paper and laptop users ($* = p < 0.05$).

majority of students in our introductory biology classes are first quarter freshman. Anecdotally these students are more attentive than upper classmen and this may contribute to the relatively low rate of off-task use.

The off-task behavior was significantly higher in Zoned compared to Control sections. The increased off-task behavior in Zoned sections is consistent with a recently reported "spreading effect" where the laptop activities of one person influenced the laptop activities of surrounding students (Lindroth & Bergquist, 2010). While this behavior did not correlate with a change in the performance metric examined in this study, it is clearly a negative aspect of zoning. It would be interesting to determine if requiring use of privacy screens, limiting the visibility of activity on neighboring computers, could help reduce the spreading of off-task behavior in laptop zones.

What are students doing when off-task? Our data indicate that approximately 40% of the students who were off-task in both Zoned and Control sections were engaged in social networking. Similarly, in a recent study, student self-reported data indicated that 25–50% of off-task time was associated with social networking activities including email and IM (Kay & Lauricella, 2011). It should be noted these could be underestimates since it is likely we missed some small chat windows in a lower corner of the screen and students may underreport their own in-class social networking. A more accurate and detailed assessment of the on-line activities would require electronic monitoring (e.g. Crook & Barrowcliff, 2001; Hembrooke & Gay, 2003; Kraushaar & Novak, 2010).

4.2. *Effect of zoning on overall student performance*

The broad range of in-coming academic indices for students in our introductory class, including AP Biology and SAT scores needs to be taken into account when working with performance data (e.g. Freeman, Haak, & Wenderoth, 2011). Therefore an Actual Z-score minus the Predicted Z-score for each student was calculated to allow comparison of performance between students with different backgrounds, in multiple sections. In contrast to our prediction, the Actual minus Predicted Z-score for paper note takers in the Control and Zoned sections were not significantly different. In addition, despite an increase in observed off-task behavior in the Zoned section there was no difference in exam performance between laptop users in Zoned compared to Control sections. This indicates that the amount and type of off-task laptop activity present in our class does not negatively impact performance of surrounding students, whether they are using laptops themselves or taking notes on paper. This is consistent with one study showing no difference in the overall exam performance between students in a class where laptops were permitted and one where they were banned (Granberg & Witte, 2005). It is possible that zoning allowed paper users to learn more efficiently in class and they had to invest less out of class time to achieve the same performance on the summative exams. This would be consistent with paper users overwhelming and often passionate support of zoning in our survey:

"moving them [laptops] to the other side = genius".

To test the hypothesis that zoning facilitates in-class learning one could compare performance between students in Zoned and Control sections on in-class activities such as challenging clicker questions.

4.3. *Potential connections between note taking strategy and individual student performance*

It is interesting to note that the laptop users had a significantly higher Predicted Z-score than paper users, largely due to higher math SAT and AP Biology scores. Thus it was surprising that the Actual Z-scores of laptop users were significantly lower than predicted and that the percentage of laptop students earning A's was significantly lower than the percentage of paper users earning A's. This is consistent with a growing number of studies that correlate lower performance to in-class laptop use (Ellis, Daniels, & Jauregui, 2010; Fried, 2008; Hembrooke & Gay, 2003; Kirschner & Karpinski, 2010; Kraushaar & Novak, 2010; Wood et al., 2011). However, none of these studies (including ours) establishes a causative link between laptop use and performance. In fact the study by Kirschner and Karpinski (2010) found indirect evidence that off-task computer use is an indicator of poor self-regulation, and not the direct cause of poor performance. The students with low grades who used Facebook the most also self-reported participating in the most extracurricular activities, suggesting that these students are not efficiently managing their time outside of class and may be easily distracted (Kirschner & Karpinski, 2010). A positive correlation between strong self-regulations skills and background knowledge, and success in computer-based environments has also been reported (Winters, Greene, & Costich, 2008). In our study laptop-users were more likely to select their note taking strategy based on ease and convenience rather than because they felt it would benefit their learning. This is in contrast to paper note takers who cite learning as an important criterion for selection of their note taking strategy, suggesting the laptop-user group had less well-developed self-regulation skills. Future studies that examine the relationship between computer-based note taking and class performance should include measures of student's self-regulation skills.

Laptop users in lecture who were observed to have off-task content on their screen were involved in at least two simultaneous activities. Although our students, the "Millennial Generation", perceive themselves to be excellent multitaskers (Prensky, 2001), available data suggests that the number of "bits" the human brain can process at once has not changed across the generations (Carrier, Cheever, Rosen, Benitez, & Chang, 2009). Although multitaskers can learn the same information as non-multitaskers, the information may be encoded differently making it more difficult for multitaskers to apply their knowledge to solving novel problems (Foerde, Knowlton, & Poldrack, 2006; Ophir, Nass, & Wagner, 2009). An additional impediment to learning while multitasking is the amount of time required for switching between tasks, potentially causing students to miss important information (Rubinstein, Meyer, & Evans, 2001). Approximately two-thirds of the questions on our biology exams require students to apply basic concepts learned in-class to new situations. Thus the effects of multitasking may be significant. This is supported by a recent study in which students tasked with using Facebook and/or messaging during lecture performed significantly worse on an exam that included higher-level questions compared to students in the "paper-and-pencil" control (Wood et al., 2011).

4.4. Effects of zoning on class environment and student attitudes

Ownership of laptop computers has increased steadily in recent years with 90% of students surveyed at 39 colleges/universities across the country in 2009 reporting they had laptops (Smith, Salaway, & Caruso, 2009). While the majority of our students own laptop computers only 25–30% of them use laptops to take notes in our large introductory biology class. The implementation of laptop-free zones in lecture did not alter the percentage of students electing to use laptops. Nor did it change the strong opposition to banning laptops reported in previous studies (Brady, 2009; Yamamoto, 2007; Young, 2006). Comments on anonymous post-class surveys indicate that at least some of this may be due to student appreciation of diversity in learning style, a theme that is overtly discussed a number of times in the class:

"I think that note-taking should be open ended because people have different learning styles."

Similar to the findings in a survey of law school students who had not experienced zoning (McCreary, 2008), the majority of our students who were in the Control section indicated they did not agree with implementing a policy that would restrict laptop use to specific areas. However, the majority of students who were in the Zoned sections supported restricting laptop use to specific areas. This is consistent with anecdotal evidence from the McCreary (2008) study suggesting strong student support for zoning in a law school class in which laptops were excluded from the first three rows in the lecture hall. Further, our study indicates that support for zoning was not limited to paper note takers but was quite high (64%) among laptop users as well.

While our study did not attempt to identify the elements of computer use that were distracting to surrounding students, recent studies reported that keyboard tapping, in addition to flashing IM prompts and rendering of websites, was distracting (Borbone, 2009; Fried, 2008). This indicates that even standard computer activity associated with note taking can also be distracting to non-laptop users. Together these findings suggest that creation of laptop-free zones is a strategy that accommodates laptop users while minimizing distractions to paper note takers in the same lecture hall and is likely to be broadly supported by students as suggested by the following comment:

"Some people like taking notes on laptops, others find the screens distracting, it's a matter of preference. I think the current set up works well to accommodate both."

5. Conclusions

Although the creation of laptop-free zones did not affect overall student performance, zoning had a positive impact on the class environment and on student attitudes. Although zoned laptop-users engaged in more off-task behavior, this wasn't associated with a decrease in performance. Thus, this is a viable strategy for faculty who wish to preserve student choice for note taking, but with minimal distraction to students who don't use laptops in class. However, students may not be making the choice that is in their own best interest. Because the variable we manipulated in this study was zoning, not laptop use, the underlying causes for why laptop users underperformed are not known. Future studies should explicitly test whether laptop users perform the same with different note taking methods, as well as include measures of the student self-regulation skills.

Acknowledgments

We thank Mark Watanabe for his assistance with data processing and analysis, the other Bio 93 faculty, and the Bio 93 classes of 2009 and 2010. This research was supported by a Howard Hughes Medical Institute Professors Program Grant to DKOD.

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