The Relative Efficacy of Handwritten Versus Electronic Student Classroom Notes

Kathy L. Pettit-O'Malley, University of Idaho, Idaho, USA
Thomas J. Liesz, University of Nevada, Nevada, USA
Sanjay R. Sisodiya, University of Idaho, Idaho, USA

ABSTRACT

As classrooms rapidly transform into high-technology spaces, a notable shift involves students' uses of laptop computers or other electronic devices to take notes. It is unclear whether the practice of recording notes electronically facilitates learning more or less effectively than does handwritten note-taking, in which students write out the material by hand. This study tests the impact of electronic versus handwritten note-taking on students' exam performance in a marketing class to address this critical question.

Keywords: note-taking, electronic note-taking, student performance

INTRODUCTION

Around the world, traditional university classrooms are being replaced with so-called e-classrooms (Kim, Turner, and Pérez-Quiñones, 2005). These increasingly complex classrooms often include, for example, a computer for the presenter's use, projection equipment, a DVD player, a document camera, white boards, and a Smart Board. Such high-tech equipment lures faculty members into using PowerPoint presentations, boosted by video clips and other glitzy displays (Lin and Bigenho, 2011). Despite the strong push for increased computer and technology use in classrooms, researchers reveal mixed results regarding the benefits of such technology uses (McKinney, Dyck, and Luber, 2009).

Coinciding with these classroom-level changes, many students now bring laptops, tablets, and smartphones to facilitate their in-class note-taking. For example, at the authors' university, business majors were required to participate in a laptop program that provided all students with identical hardware and basic software. Thus, faculty could mandate that students use programs such as Excel, Access, and so forth, both for homework and during classroom exercises.

While the use of technology in the academic setting seems like a logical bridge for students as they prepare for careers outside of the classroom, some faculty express reservations about student use of laptops and other devices in the classroom (e.g., Yamamoto, 2007). The human mind is prone to wander at times, as has been shown to occur when students use electronic devices (Hollis, 2013). The experience at our university reveals that our colleagues are mainly concerned about learning—or its lack thereof—in the classroom. Although certainly some students surf the Web, text message, or play video games rather than focusing on class discussions, the faculty concerns are more wide ranging. Beyond the simple misuse of laptops, various instructors have come to question the effectiveness of electronic note taking. To further explore this issue, in this study we investigate the following research question: Does it make a difference in terms of student learning and exam performance, it a student takes notes by hand as opposed to electronically?

In the next section, we offer a review of these two forms of note-taking. We then present our research methodology where we test our hypothesis in a classroom setting. The results suggest that the mode of note-taking does influence learning outcomes. We conclude with a discussion of the results, implications, and directions for further research into note-taking.

BACKGROUND

In traditional note-taking practices, students listen to classroom lecture or discussions, deduce the important points, and write them down for (potential) future reference. Note-taking has long been a ubiquitous practice among college students; four decades ago, Palmatier and Bennett (1974) reported that 99% of students took notes during

instructors' lectures. In addition, students perceived note-taking as useful, according to Dunkel and Davy's (1989) finding that 94% of U.S. college students surveyed considered taking notes "pivotal" to their assimilation of lecture content.

There may be evidence that suggests that notetaking methods do influence performance. There is anecdotal evidence suggesting that note-taking may influence learning. Clark (2014) recently reported that each member of the Cleveland Browns professional football team was given a pad of paper upon which to take notes as they learned the new playbook. Every other NFL team gives their players a tablet computer with the playbook pre-loaded. Mike Pettine, head coach of the Browns, was quoted as saying, "To write down is to learn". In a recent study by Perez-Hernandez (2014), the author found that even though students taking notes by hand took barely half as many notes as their counterparts taking notes on a laptop, they scored significantly higher on a test of recall 30 minute later. This also suggests that there may be differential learning effects due to the method of note-taking used.

Taking notes by hand requires greater effort than taking them electronically (Piolat, Thierry, and Kellogg, 2004). Also, for handwritten forms of note-taking, some researchers (c.f., Aiken, Thomas, and Shennum, 1975) have suggested that the inherent division of attention (i.e., split between attending to the presented material and engaging in a recording task) may render note-taking less useful than if the instructor were to provide summaries of the lecture content. Aiken, Thomas, and Shennum found somewhat better retention when note-taking followed listening, compared with simultaneous tasks. However, Thomas (1975) argued that notes taken during information presentation or immediately thereafter appear equally facilitative of subsequent recall. Thomas also reported that note-taking was significantly more facilitative of recall than was reviewing a summary of the lecture provided by an instructor. A subsequent study affirmed that an instructor-supplied summary was inferior to student note-taking for college students' acquisition of economic principles (Cohn, Cohn, and Bradley, 1995).

Such note-taking research often addressed the distinct roles of student note-taking, whether as a means to ***encode*** material in memory or as an external ***storage*** vehicle for information, held for subsequent review or studying. Regarding the encoding function, Kiewra (1989) found that when students take notes, but never review them, the note-taking process itself facilitated recall. In terms of storage, the review of notes—whether taken by the student him- or herself or provided by another student or the instructor—also improves subsequent recall. The validity of information contained in notes provided by another student is a separate issue, beyond the scope of this article.

Other early research also has addressed the efficacy of training people in note-taking or note-reviewing techniques. For example, in a study of pertaining to note-taking, Carrier and Titus (1981) explained to students how to (1) distinguish between superordinate and subordinate information, (2) abbreviate words, (3) paraphrase lecture statements in the students' own words, and (4) use an outline format. This training facilitated students' subsequent recall, particularly when they expected an essay format of testing. Furthermore, training students to self-question while reviewing their own notes can facilitate recall more than merely training them to summarize material from their notes during review sessions. Both review methods resulted in superior recall, compared with the results achieved with no instruction on methods for reviewing notes (King, 1992).

More recent research attention has targeted the efficacy of note-taking to promote sharing of notes. Specifically, research has been conducted concerning handheld or larger electronic devices, including personal data assistants, tablet computers, and laptops, for note dissemination among students (Davis, Lin, Brotherton, Landay, Price, and Schilit, 1998; Kim et al. 2005; Landay, 1999; Landay, Davis, Chen, Huang, Lee, Li, Lin, Morrey, and Schleimer, 1998; Moran, Palen, Harrison, Chiu, Kimber, Minneman, van Melle, and Zellweger, 1997; Rekimoto, 1998; Stifelman, Arons, and Schmandt, 2001). In addition to investigations of whether electronic-assisted note-taking improves users' ability to share notes (Davis, Lin, Brotherton, Landay, Price, and Schilit, 1998; Landay, 1999; Landay, Davis, Chen, Huang, Lee, Li, Lin, Morrey, and Schleimer, 1998), other research has advocated use of electronic devices to capture additional elements of the surrounding environment within students' notes, such as with video or auditory recordings (Chiu, Kapuskar, Reitmeier, and Wilcox, 1999; Moran, Palen, Harrison, Chiu, Kimber, Minneman, van Melle, and Zellweger, 1997; Rekimoto 1998). Furthermore, Kiewra and colleagues (Kiewra, 1989; Kiewra, Mayer, Christian, Dyreson, and McShane, 1991) showed that allowing students to review a recorded lecture up to three times, and instructing them to take different notes each time they viewed the material, produced more complete notes. Although the most important information tended to be recorded in initial notes, students added less important, related clarifications or supportive information after subsequent viewing(s). Although these studies did not test recall after each viewing and note-taking session, better notes (i.e., more complete)

seemingly should facilitate subsequent recall. As Weener (1974) reported, the probability that a student recalled an item during a test was higher if that item appeared in his or her notes.

Unfortunately, until very recently, research into electronic notetaking paid little attention to either information recall or the relative efficacy of electronic versus handwritten note-taking. The scant earlier research begs the question of the effectiveness of electronic note-taking. According to Bui, Myerson, and Hale (2013), electronic note-taking may improve immediate recall on tests. Yet, in a survey of 35 computer science graduate students and human–computer interaction researchers regarding their note-taking methods and preferences (Kim et al., 2005), three-quarters of those computer-savvy people preferred taking handwritten notes to using electronic-assisted means. Only five respondents indicated a preference for computer-assisted note-taking, offering reasons such as preferring to type their notes, the ability to search for related material while recording notes, data entry speed, neatness of typed relative to handwritten output, and perceptions of greater information security. In contrast, the majority who preferred to hand record their notes complained about the difficulty of drawing within typed notes (e.g., diagrams, arrows connecting topics). They also reported that taking notes by hand provided more flexibility in placing material and greater capability to be expressive. Additionally, they viewed handwriting (versus keyboarding) as faster, which suggests that relative typing speed may influence note-taking medium preferences. Across all respondents, whether they preferred electronic or handwritten notes, typing as a means of note-taking seemed *neither particularly natural nor efficient*. As one participant in Kim et al.'s study (2005) commented, "I remember much more of what I write than what I type. In fact, most of the time, I won't remember much of anything that I type, while I can remember a great deal more of what I hand write."

This reflection is consistent with physiological findings provided by Katanoda, Yoshikawa, and Sugishita (2001). In a functional MRI study, they investigated which portions of the brain became activated when participants wrote down names of pictured objects, named pictures silently, or engaged in visually cued finger tapping, which is similar to typing. By comparing the brain activities in the three conditions, the researchers discovered that very different areas of the brain were involved in handwriting versus typing. Briefly, tapping alone is right-brain–dominant activity, whereas both hemispheres of the brain appeared equivalently activated by writing alone. If the naming function were added, writing became a left-brain–dominant activity. Thus, writing appears to *require* the activation of certain cognitive sections of the brain, but typing (finger tapping) does not require left-brain activation. People might choose to both think and type, but they can also type on "automatic pilot."

A single, recent study (Mueller and Oppenheimer, 2014) investigated the relative efficacy of note-taking either by hand or electronically. In a series of three laboratory experiments, they found that electronic note-taking resulted in reduced performance in answering conceptual questions than did note-taking by hand. They reported that, "whereas taking more notes can be beneficial, laptop note takers' tendency to transcribe lectures verbatim, rather than processing information and reframing it in their own words, is detrimental to learning" (p. 1).

Thus, for the current investigation, we expect that writing notes by hand affects the encoding of information in memory, and also provides external storage (i.e., on paper), whereas typing may be effective only as a means to store material for future analysis. In this case, classroom time seemingly could be somewhat wasted, in terms of learning, if students are typing notes. If this typing occurs without corresponding thinking, the clarification questions that should be asked during information presentations could also go unasked. In our attempt to determine the relative efficacy of student note-taking by hand or through electronic means, we reflect on previous research and accordingly propose the following hypothesis:

Hypothesis: Students taking hand-written lecture notes will perform significantly better on related essay test questions than those who take notes electronically.

Although several other variables can affect student test performance, this quasi-experimental study seeks to identify the potential effect of note-taking method on subsequent test performance in an actual classroom environment.

METHODOLOGY

Our methodology aimed to extend existing research that had utilized an artificial laboratory setting (e.g., Mueller and Oppenheimer, 2014), to a natural classroom environment. Two sections of an introductory integrated business curriculum (IBC) class participated in the study, which took place during the third month of the course. At the university in which the experiment was conducted, IBC was taught by a five-member faculty team, represented by

one professor each from finance, information systems, management and human resources, marketing, and operations management. Classes met for nine hours per week during the first semester, and eight hours per week in the second semester. The IBC class covered basic concepts in several functional business areas, and associated presentations and discussions attempted to help students integrate the concepts into a meaningful view of business as a whole. The sample included first-semester juniors majoring in accounting, economics, finance, information systems, management and human resources, marketing, and operations management. The sample was 66% male/34% female, with participants ranging between 20 and 22 years of age.

Students were informed that the instructors intended to conduct research on the potential relationship between student note-taking methods and subsequent exam performance. Of the approximately 100 students (i.e., about 50 per section) in the IBC sections, 54 voluntarily agreed to participate. Students were assured that they would be free to choose their preferred note-taking method(s)**,** and could change it at any time during the study. Each student maintained a detailed record of his or her note-taking method(s) when the class covered any of 14 marketing-related topics. Those topics were presented over a six-week period, which bridged two exams. All marketing topics were presented by a single instructor. Each day that she taught, the marketing instructor reminded students to record their method(s) of capturing notes, on a topic-by-topic basis. Student note-taking method diaries were not collected until after both exams with related essays had been administered, graded, and returned to students.

The two separate exams that provided the performance tests took place three weeks apart, and the marketing essay questions were written and graded by the same instructor who had presented the marketing-related material. In IBC all exams were numbered, and one's number related to which calculator he/she had drawn from a box provided by the proctor before the student took a seat for the test. One's test number differed from exam to exam, and the only place in which a student's name was associated with his/her number was on a cover sheet, which was taken by the teaching assistant to create a list for use after the exams were graded. Since no names appeared on essay responses, no instructor grader knew whose response he/she was grading. Thus, the instructor who graded the marketing-related questions included in the study was blind as to the note-taking method chosen by each respondent until after the graded exams had been returned to the students and the experiment had been terminated.

During the coverage period students were prompted to fill in an hourly table describing their note-taking method(s) at the end of each three-hour class period. Of the 14 potential topics related to the note-taking method data, three appeared as exam questions. Other exam questions, such as those from other functional areas, or that integrated material from more than one topic, were excluded from the analysis. This was done to insure that we knew their related note-taking method, and that students' note-taking methods were consistent within the question's topic. Student participants were unaware of which marketing topics would serve as a basis for the research-related exam questions.

Students self-selected into teams for various class projects throughout the semester. They were not required to study for exams in those same teams, but many chose to do so. Slightly fewer than half of the teams initially volunteered to assign one member to taking electronic notes, while the other members would take class notes by hand during the experiment-related portions of the class. Thus, one member of each handwritten note "team" would fill in blanks in incomplete PowerPoint slides, which had been prepared by the instructor and provided electronically to students before the related material was presented. Thus, all students had access to a complete set of notes about the related material. Which member of each team filled in Power Point slides electronically could vary from one class session to another, as determined by the participants. An example of a fill-in-the-blank slide would feature a particular target-marketing strategy (e.g., undifferentiated), and would provide the terms "Advantages" and "Disadvantages." Students would then either hand write advantages and disadvantages in their notes, or type them into their slides.

Other student teams self-selected into the electronic notes condition, taking notes electronically, in whatever fashion they chose. The note-taking record provided by each participant distinguished between handwritten and electronic note-taking, and also included more detailed information about the electronic methods they selected (e.g., One-Note, fill-in-the-blank Power Point, Word, etc.). During the quasi-experiment each student could use whatever note-taking method he or she believed was most useful for particular material. Thus, some participants crossed between treatments during the study.

Exams in IBC relied entirely on essay responses, and were conceptual in nature. Some essay questions pertained to a particular functional business area; others integrated material from more than one functional area. By linking the

scores on questions tied to particular marketing topics to note-taking methods, we specified our dependent variable as the percentage score on each of three 20-point essay questions.

Student exam performance has been found to relate to many factors, including student aptitudes, skills, motivation, and learning-related self-efficacy beliefs, as well as instructor attributes and instruction quality (Devadoss and Foltz, 1996; Zimmerman and Martinez-Pons, 1992). Since the same instructor presented all material related to marketing topics, using the same Power Point slides in both class sections, instructor-related variables and instruction quality remained constant across the note-taking methods.

All students had equivalent previous business-related classes (accounting, economics, business law, business writing, statistics, and mathematics). They had not taken previous classes in marketing. All the lectures for which the related questions served as dependent measures pertained to marketing topics (i.e., market segmentation and targeting, marketing research, and consumer behavior).

Exams contained multiple marketing-related essay questions, and students could select a subset of those questions to answer. Thus, the cell sizes were not equivalent, ranging from 9 (consumer behavior, hand-written notes) to 23 (marketing research, electronic notes), with an average of about 17 per Exam-Topic by Note-Taking Method combination. Question 1 (market segmentation/targeting) appeared in the fourth exam of the semester, and questions 2 and 3 (marketing research, consumer behavior) were included in exam five. Thus, differences in performance across questions could reflect either a learning curve effect, and/or topical and question difficulty differences.

RESULTS

In a preliminary analysis, we employed class section as a potential predictor variable, but found that performance on the essay questions did not differ between sections. As such, we did not include it in subsequent analyses. Similarly, while college major could have related to motivation and aptitudes, and could have affected essay question performance, it was also dropped from subsequent analyses when it was found that the confidence intervals for marketing and non-marketing majors overlapped.

As an initial analysis, we divided the participants into three GPA strata. Mean question percentage scores are shown for each GPA Third and Note-Taking Method in Table 1. Before analyzing the effects of Note-Taking Method on essay question performance, we wanted to determine if choice of note-taking method was related to previous GPA. It could be that "better students" would be more likely to have learned that taking notes by hand resulted in better exam performance. Note-taking method was significantly related to GPA Third ($F_{2,81} = 3.850$, $p < .05$). As can be seen from Table 1, for both the top and middle GPA strata, selection of note-taking method was about half and half. However, for the lowest GPA third, a much smaller percentage chose to take notes by hand. A Duncan's Multiple Range Test, at $p < .05$, revealed that the top and middle GPA strata were a homogeneous subset, and that the bottom GPA stratum was a separate subset in terms of likelihood of taking notes by hand. Due to the significant differences, all further statistical tests were conducted within GPA strata.

Since we had identified both question topic and note-taking method as potential sources of variation in question percentage scores, we used stepwise regression within GPA strata to analyze the data, and allowed the data to drive the results. In Tables 2 and 3, we present the R^2 and F test results from the stepwise regressions. As can be seen from Tables 2 & 3, for the top GPA stratum, only Note-Taking Method entered the equation (adjusted $R^2 = .130$). Table 4 shows that for the top GPA stratum, Note-Taking Method was significantly related to Q%Score ($t = 3.134$, $p < .01$).

As can be seen in Tables 3 and 4, for the middle GPA stratum Question Topic and Note-Taking Method entered the equation, in that order (adjusted $R^2 = .367$, $p < .001$). Table 4 shows that both Question Topic ($t = 4.515$, $p < .001$) and Note-Taking Method ($t = 3.527$, $p < .01$) were significantly related to Q%Score, indicating that the mid-third GPA students performed better on some essay questions and topics than on others. More importantly, as had been hypothesized, those taking notes by hand during class scored significantly better on the marketing-related essay questions than did those who had taken notes electronically.

Finally, turning to the bottom GPA stratum, only Question Topic entered the equation (adjusted R^2 = .082). For the "poor student" group, which question was answered significantly related to Q%Score ($t = 2.487$, $p < .05$), as can be seen in Table 4. As can be seen in Table 1, very few bottom GPA students chose to take notes by hand.

Because the cell sizes were unequal, we performed a Type III Sum of Squares Analysis of Variance (c.f., Lane, undated; Maxwell and Delaney, 2003) to determine if observed results could be attributed to the unequal cell sizes. Within the same GPA strata used in preceding analyses, we found that the same factors which had been found to be significant in the stepwise regressions remained significant in the Type III Sum of Squares Analysis of Variance, indicating that the unequal cell sizes did not create spurious results.

As can be seen from Tables 3 and 4, for both the top and middle GPA strata Note-Taking Method was significant and entered the equation. Specifically, Note-Taking Method, alone, was significantly related to Q%Score for the top GPA group. Both Question Topic and Note-Taking Method related significantly to essay question performance for the middle third GPA stratum. Only for the bottom GPA group was Note-Taking Method unrelated to performance on related essay exam question. Given that Note-Taking Method remained a significant predictor of Q%Score for the top two-thirds of students as defined by previous GPA, we concluded that the effects of Note-Taking Method went beyond a "better student" interpretation. That is, even after allowing for previous success as students, the top two-thirds of students still improved their performance by taking notes by hand.

DISCUSSION

Academic test performance relates to many different factors, including both instructor- and student-related variables. Instructor characteristic and quality of instruction, along with the nature of the class lectures and discussion, can influence student performance measures. Other instructor-selected variables, such as nature and structure of exam questions, and their subsequent grading, can also effect student test score outcomes. Noting these effects, we held instructor- and instruction-related variables constant by using a single individual for instruction, question creation, and grading of the marketing-related essay questions.

In terms of student-related variables, aptitudes, skills and motivation can all affect academic test performance. We sought to control for differences in student aptitudes and skills by dividing respondents into GPA strata, before running analyses to test the effect of note-taking method. Additionally, by selecting two sections of a class whose students were extremely homogeneous in background courses (e.g., accounting, economics, statistics, business writing and math) which could affect comprehension of the marketing material, we were better able to isolate the effect of note-taking method.

Many business academics, though highly knowledgeable in their various functional areas, are less well versed in pedagogical issues. Furthermore, the meaning of best pedagogy practices continues to change rapidly, especially with the advent of electronic classrooms and the arrival of students who have grown up with electronic multitasking. Just as instructors may be less than perfect in their pedagogical methods, so are students imperfect in their learning techniques. For example, students may believe it is easier—*and equally effective*—to use classroom time for accurate (electronic) recording of classroom notes, with the presumption that areas of potential confusion can be subsequently clarified merely by studying their notes or discussing the material with fellow students. The choice by many students to adopt electronic note-taking emphasizes the recording aspect of this task, leaving the encoding portion either wholly or partially deferred until a later time. Figuring out meaning requires more mental effort than merely recording information presented in class. In this sense, the concept of the present value of time may be something that instructors do not have to teach; students appear to understand it already. It is just plain easier to record now, and leave the figuring-out until later.

A superiority in handwritten note-taking methods was previously found and reported by Mueller and Oppenheimer (2014). Their study showed that those who took notes electronically recorded significantly more material, but did less encoding of the material. As such, when their participants were allowed to study prior to being tested, those who had taken notes by hand outperformed those who had taken them electronically. This held even when participants were instructed to take notes in their own words, rather than writing down notes verbatim.

Taking notes by hand ultimately leads to superior learning of the presented material and thus improved test performance. This evidence suggests that instructors should encourage students to take handwritten notes during

class, which could be accomplished through various means. Although an open and frank discussion of the superiority of handwritten notes seemingly should suffice, this approach did not meet with overwhelming success when we attempted to implement it, as demonstrated by the smaller cell sizes in the handwritten condition. In addition, among the 46 students who chose not to participate in the study, the majority used electronic means to take notes. Thus, though both faculty and students seem critically aware of the additional effort required to take handwritten notes, students used in this study did not appear to realize the superior value of handwritten notes, in terms of producing learning and enhancing exam performance, or in being willing to make the greater effort-related investment during class.

It should be recalled that the classes were informed of our hypothesis concerning the superiority of taking notes by hand prior to any presentation of the related class material, and before they selected means for taking notes on each section of material. Yet, for the top two-thirds of the classes in terms of previous GPA, half still chose to take notes electronically. We have no way of knowing how the proportion of electronic- to hand- notes would have been among the "better students," had we not shared our beliefs with them in advance. Additionally, after controlling for previous GPA, in both the top and middle GPA strata Note-Taking Method did relate significantly to essay question performance. Specifically, the top two-thirds of participants by GPA performed significantly better if they took note by hand, rather than electronically, just as had been found by Mueller and Oppenheimer (2014). Clearly, the word needs to get out, even among the previously more accomplished students.

Our results revealed that note-taking method did not relate to essay question performance for the bottom GPA stratum. Thus, rather than a "better student effect" – that more accomplished students would have already learned that taking notes by hand results in superior performance and would thus select that method – we may have uncovered a "poorer student effect." It may be either that the previously-identified weakest third did not have adequate motivation to take notes by hand, and/or did not possess the note-taking skills assumed in our predictions. Specifically, we presumed that when one takes notes by hand, he/she encodes them (i.e., translates concepts into one's own words), rather than merely trying to stenographically record them, verbatim. Some of the weaker GPA students who tried to take notes by hand may have not only lost out on the encoding advantages, but may also have ended up with an incomplete transcription of the notes. Since we did not collect notes form the student participants, we cannot do a content analysis of them. Thus, this is only a guess on our part. But, if subsequent research determines that weaker students lack solid note-taking skills, it may be something that universities need to teach to incoming students.

Because most people learn better by doing than by listening, the current study sought to help students recognize this point for themselves. We shared the results with the students, in the hope of improving their self-efficacy beliefs with regard to preparing for exams. Another potential method to encourage students to take handwritten notes would be to withhold copies of the instructor's notes from students, or to provide them with only abbreviated, electronic versions of the notes, after the presentation of the material and related discussions in class. If an instructor realizes that certain material is particularly complex or requires careful encoding, he or she could also ask students to close their laptops and take notes the old-fashioned way.

Even with these findings, we urge caution in interpreting our results or making broad generalizations. The human mind is prone to wander at times, and with students' ready access to laptops, those taking electronic notes might deviate more easily from classroom learning activities, and split their focus away from the material at hand. Faculty concerned with student engagement in electronic classrooms thus may need to consider additional mechanisms to minimize distractions and wandering minds, if they hope to enhance student learning.

LIMITATIONS

In this quasi-experimental research, the participants were not only aware of the research hypothesis**,** but also could self-select note-taking method. Thus, determination of a causal link between note-taking method and exam performance is tentative, despite our use of other potential predictor variables to try to isolate its role. Although it seems unlikely that students selecting to use electronic means of taking notes would intentionally risk their grades in an effort to support the research hypothesis, that interpretation represents a competing hypothesis to explain the findings.

Another concern might revolve around the representativeness of the sample. Mueller and Oppenheimer's (2014) previous experimental studies demonstrated the superiority in test performance when a laboratory setting was used,

and participants could be randomly assigned to note-taking methods. However, our interest was to see whether that superiority of taking handwritten notes would occur in a more natural setting, and when students were allowed to take notes by whatever means they preferred. While our selected quasi-experimental method is not as strong in internal validity as a true experiment would have been, it does have stronger external validity with participants, leaning and testing situations similar to those found here. Our study was conducted in an accredited business school at a state university. At our university most students attend full time and live in residence. Our sample was homogeneous in terms of the participants' academic background (starting their junior year; previous foundation courses in accounting, economics, business law, business writing, and mathematics) and their age (20–22 years). Caution is required in generalizing the results to other, dissimilar student populations.

Additionally, the nature of the testing involved use of essay questions related to class discussion. As such, they were conceptual and application oriented, much more so than factual recall tasks. That type of testing was found by Mueller and Oppenheimer (2104) to be favor handwritten note-taking, over electronic note-taking. Many classes which have a large factual-based content may not show the same marked superiority in test performance among those taking notes electronically.

Although the marketing topics for the three questions were somewhat different from each other, certain types of material and learning elements were not tested by the current study. For example, none of the topics included mathematical problem-solving. It appears unlikely that students would choose purely electronic means of note-taking with quantitative material, as formulae are difficult to record quickly with a tablet or laptop. However, for courses in statistics, mathematics, and other problem-oriented concepts, the use of electronic devices may be highly beneficial in problem-solving. If students can work through problems by themselves, using some problem-solving software (e.g., Excel, SPSS, SAS), it likely requires greater left-brain activation than would electronic note-taking of verbally presented material. In these cases, electronic means for such "note-taking" may prove highly effective in producing the learning desired by both faculty and students.

We also acknowledge that the superiority of handwritten notes over computer-generated ones in our research pertains only to standard note-taking, and does not relate to use of concept mapping. Further research is needed before we can apply the current research findings to other types of material or other means of learning. What we suggest is testing this for yourselves in your own classes, and seeing whether it leads to enhanced understanding.

Table 1. Essay Question Percentage Scores by Previous GPA Third and Note-Taking Method[a]

					95% Confidence Interval	
GPA Third	Note-Taking Method	Mean	n	Std. Error	Lower Bound	Upper Bound
Top	Electronic	82.308	13	4.752	72.843	91.772
	Hand-Written	88.929	14	4.579	79.808	98.049
Middle	Electronic	56.667	15	4.424	47.855	65.478
	Hand-Written	80.769	13	4.752	71.305	90.234
Bottom	Electronic	71.136	22	3.653	63.861	78.412
	Hand-Written	65.000	5	7.663	49.739	80.261

a. Dependent Variable = Q%Score

Table 2. Model Summary within GPA Strata

GPA Third	Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
Top	1	.381[a]	.145	.130	14.43041
Middle	1	.503[b]	.253	.240	16.37198
	2	.624[c]	.389	.367	14.94104
Bottom	1	.313[b]	.098	.082	17.39414

a. Dependent Variable = Q%Score
b. Predictors: (Constant), Note-Taking Method
c. Predictors: (Constant), Question Topic
d. Predictors: (Constant), Question Topic, Note-Taking Method

Table 3. Effects of Question Topic and Note-Taking Method on Question Scores within GPA Strata[a]

GPA Third	Model		Sum of Squares	df	Mean Square	F	Sig.
Top	1[b]	Regression	2045.601	1	2045.601	9.823	.003[b]
		Residual	12077.732	58	208.237		
		Total	14123.333	59			
Middle	1[c]	Regression	5175.020	1	5175.020	19.307	.000[c]
		Residual	15278.370	57	268.042		
		Total	20453.390	58			
	2[d]	Regression	7952.242	2	3976.121	17.811	.000[d]
		Residual	12501.148	56	223.235		
		Total	20453.390	58			
Bottom	1[c]	Regression	1871.256	1	1871.256	6.185	.016[c]
		Residual	17245.694	57	302.556		
		Total	19116.949	58			

a. Dependent Variable: Q#Score
b. Predictors: (Constant), Note-Taking Method
c. Predictors: (Constant), Question Topic
d. Predictors: (Constant), Question Topic, Note-Taking Method

Table 4. Coefficients[a]

GPA Third	Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
Top	1	(Constant)	74.730	2.372		31.500	.000
		Note-Taking Method	12.009	3.832	.381	3.134	.003
Middle	1	(Constant)	52.082	5.403		9.639	.000
		Question Topic	6.534	1.487	.503	4.394	.000
	2	(Constant)	48.443	5.038		9.616	.000
		Question Topic	6.148	1.361	.473	4.515	.000
		Note-Taking Method	14.541	4.123	.370	3.527	.001
Bottom	1	(Constant)	63.068	5.741		10.986	.000
		Question Topic	3.929	1.580	.313	2.487	.016

a. Dependent Variable: Q%Score

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