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# Collaborative Note-Taking: The Impact of Cloud Computing on Classroom Performance

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This article presents the early findings of an experimental design to see if students perform better when taking collaborative notes in small groups as compared to students who use traditional notes. Students are increasingly bringing electronic devices into social science classrooms. Few instructors have attempted robustly and systematically to implement this technology to facilitate student learning. This study examines the efficacy of using technology to improve student note-taking. Cloud-based collaborative software makes it possible for the first time to break down the most basic walls that separate students during the process of taking and encoding notes. Collaborative note participants used Google Drive under direction of an instructor to assess performance differences. Strong evidence is found that such groups improve grades and related learning outcomes.

Content in most social science classrooms is still primarily delivered via lecture. That quintessential collegiate institution, the classroom, remains familiar in its static delivery of content. Students individually and in isolation take notes while a professor speaks. If students are encouraged to collaborate, that interaction is solely outside the confines of the class and typically not encouraged during the lecture. While there are often times of group discussion or interaction, these are not typically during the lecture, movie, or multimedia event. Current research demonstrates that interaction actually decreases the amount of note-taking during a class session (Boch & Piolat, 2005). From chalk to PowerPoint, technology has not disrupted the normal classroom environment.

Yet there are pedagogical reasons for wanting to overcome the isolation inherent in the contemporary classroom. Modern cognitive theory has uncovered that "learners must be actively engaged in learning" to achieve deep understanding (Barkley, Cross, & Major, 2005, p. 10). Pedagogical research has demonstrated that good undergraduate education includes meaningful and extensive contact between students as well as between students and faculty, both of which encourage active learning. As early as 1994 there was evidence that collaboration could advance problem solving and critical thinking skills (Alavi, 1994). Earlier still Johnson, Mesch, and Johnson (1988) found that cooperative learning arrangements increase measures of achievement, higher-level reasoning, frequency of new ideas, and situational transfer. In his seminal work on writing across the curriculum, critical thinking, and active learning, Bean (2011) emphatically emphasized the need for small group collaboration in the classroom. In short, there is an emerging consensus that our creativity and learning are enhanced by social interactions (Resta & Laferrière, 2007).

Nowhere has the isolating effects, so devastating for critical thinking, been so pronounced as during the act of note-taking. Note-taking, at its most basic, has been defined by educational psychology as the condensation of material while simultaneously interacting in other ways with a given material set (Piolat, Olive, & Kellogg, 2005). During a traditional lecture students have time limitations which requires unique summarization and leads to "much diversification in note-taking practices" (Piolat et al., 2005, p. 293). But how effective are these practices? What are students actually gaining from this skill set quantitatively?

Typically, students are involved in a form of "copy-regurgitate" strategies (Boch & Piolat, 2005, p. 102). Students copy lecture material down in order to later perform well on tests. These kinds of notes are about the passive production of information, and the notes are a process of enhancing internal storage (Kiewra, 1987). It is also a way to focus attention. Note-taking requires a listener to be more connected to a speaker or document (Piolat et al., 2005). The problem is that although students rely on this method, its efficacy has been demonstrated to be inadequate in the classroom setting (Ambruster, 2000; Kiewra, 1985; Makany, Kemp, & Dror, 2009). The problem found in the literature is that students are not efficient note takers, meaning they only successfully capture information about 20% of the time, and they are organizationally flawed and therefore miss how information should fit together. These shortcomings, efficiency and organization, are particularly acute in individuals taking notes on a computer alone (Mueller & Oppenheimer, 2014). Mueller and Oppenheimer (2014) specifically find that computers – when used in isolation – lead to lower levels of information retention, and they postulate this is due to students trying to be stenographers with keyboards instead of actively engaging with the material.

Given the numerous problems of normal note-taking practices, much research has examined the effects of particular note-taking techniques in order to assess how it might be improved (Makany et al., 2009). Makany et al. (2009) are particularly interested in

finding ways to help improve information retention. These include clustering, concept mapping, the Cornell system, idea mapping, instant replays, knowledge maps, learning maps, mind mapping, model maps, and others. There is a consensus emerging that the key to note-taking is the ability to select, encode, and organize information (Robinson, Katayama, DuBois, & DeVaney, 1998; Samarawickrema & O'Reilly, 2003) and that well-structured notes lead to better learning outcomes (Titsworth & Kiawra, 1998, 2004). Traditional lectures and notes have been demonstrated to lead to less information transfer, less structure, and less learning than was previously thought.

Within the context of these many options, much pedagogical research has focused on creating and proposing systems for improving note-taking. Among the suggestions is the use of collaborative notes (Kam et al., 2005; Kobayashi, 2006; Miyake & Masukawa, 2000; Wu, Chen, Chen, & Chiu, 2009). Collaborative notes are mechanisms by which students summarize lecture (or other material) jointly and simultaneously. Typically such collaboration occurs in small groups (three to four students) who work together to produce a single notes document.

Unfortunately, the techniques presented in the literature are often implemented by obscure, expensive, technical software or forms not immediately user friendly (Kittle & Hicks, 2009). Additionally, prior proposals have had pricing and familiarity issues. Expensive and unfamiliar software is simply not a realistic possibility for many universities and colleges. Despite many suggestions for changing how students take notes, none have displaced the normal model. The few suggestions that do exist are not readily available in most academic settings.

As a result of these shortcomings, those interested in writing pedagogy and collaboration have recently turned to Google Drive (Kittle & Hicks, 2009). Their reasoning is Google offers three primary services not available with other tools (like wikis or specialized software): (a) users can interact inside the program, (b) Google saves are made automatically and simultaneously, and (c) Google Drive informs users of changes by other writers. Writing pedagogy—highlighted by the now ubiquitous Writing Across the Curriculum (WAC) and Writing in the Disciplines (WID) programs—now makes a strong case for the use of digital collaboration, but that work has not yet extended its research to the broader classroom environment or the process of note-taking.

The goal of this work is twofold: to bring small groups into the classroom and improve student learning via collaborative notes using non-specialized software. Given that half of the variance of students' test scores are related to lecture notes (Titsworth & Kiewra, 1998), professors should be deeply interested in ways of improving the note-taking process. This project begins where the varying research threads have left off. How can we increase student collaboration while improving note-taking practices? Further, how is this accomplished without disadvantaging students and colleges who may not have access to expensive or specialized software? The current work attempts to bridge an unfortunate gap between the well-intentioned goal of collaboration and improved note-taking in earlier pedagogical work and the pragmatic reality that faculty face in the classroom.

## Project Overview

One of the most important technological advances has been the advent of the *cloud*. Cloud computing has altered the way data is processed and stored. Instead of computers being isolated units, cloud computers run software and functions on remote servers that can be accessed by any local client. The unique possibility presented by such a paradigm shift is that multiple users can run the same program simultaneously and thereby interact with one another. For word processing, this means that multiple users could access, create, and edit the same document.

A variety of cloud software is available for word processing, but for the purposes of creating a collaborative space in which students can take notes together, Google Drive was chosen due to the literature on writing noted earlier (Kittle & Hicks, 2009). It must be noted that a variety of other software could also be used; the newest versions of iWork allow for collaborative real-time editing (including for tablets). Microsoft Office 360 is working on implementing real-time editing. Emergent tools such as QUIP are also becoming potential editing packages. For the purposes of this study the goal was something that was device agnostic: there are versions of Google Drive for iPhone, iPad, Android phones and tablets, and even for every variety of laptop including Linux. It was also desirable to use software that had been previously tested in earlier studies.

Google Drive is a hard drive in the cloud. It allows files to be stored remotely and accessed from any computer. In addition, Google Drive comes with a free tool, Google Documents. Documents allows for editing remotely in a word processor that is on any tablet or computer. Multiple users can edit the same document, chat, and work together in real time. Importantly for student buy-in, unlike other office suites (such as the dominant Microsoft Office), Google Drive is completely free. The no-cost entry means that any student, at any level of institution, can participate. Expensive software is possible at some universities, but for many teaching institutions such costs are prohibitive.

Unlike traditional, locally based word processors, Google Drive can be used by a nearly unlimited number of individuals at the same time. Central to the current context, users can actually edit a single document simultaneously. One of the key failings of traditional notes is trying to record information while simultaneously processing that same information. But what if more than one student were able to work together? Could this offload some of the mental shortcomings of traditional, individualized notes? This research tests the effects of collaborative note-taking on class performance both qualitatively and quantitatively across a spectrum of classes.

The experiment was relatively simple: allow students to use collaborative notes in small groups (three to four students) and compare experiences and performances between those who used collaborative notes and those who did not. Further, compare outcomes between classrooms that participated in the experiment and control classrooms. It was also possible to administer a pre-/post-test in order to evaluate if the notes themselves were a defining factor in learning outcomes. The classes in the experiment were introductory political science and psychology classes. All classes were from state colleges.

Students freely volunteered at the beginning of each semester to participate in the collaborative note-taking. Professors (or a teaching assistant) who participated would explain to their classes about Google Drive and the possibility of joining small groups to take notes simultaneously in class. This presentation was done during the first week of each semester. Students then opted into the study if they so chose and remained part of the process for the duration of the semester. From the larger body of participants, students then freely entered into smaller note-taking groups however they wished or were randomly assigned into smaller groups by the professor or teaching assistant.

Each professor (or teaching assistant) created a blank file in Google Drive for each small group in the class. As a result, classes had multiple small groups. One American government class in the fall of 2012, for example, had four small note-taking groups of three to four students. These collaborative note groups had their own independent Google Drive document. Therefore, each class had multiple collaborative small groups, and this was constant across all classes.

Letting the professor or teaching assistant author the file granted the instructor access and ownership of each group's notes in case of disputes or issues during the semester. It also allowed for the instructor to get real-time feedback on how well students understood any particular set of lectures. Professors were able to engage students in a new way by having the ability to tailor content and get a feeling for the performance of students by the notes they were taking—a feature not possible with traditional notes. For example, in the spring of 2013, I modified and altered lectures on a section on civil liberties due to the way students were taking notes (such changes were implemented the following semester).

## Methodology and Results

In order to assess the effects of collaborative note-taking, the following two strategies were employed:

- A quantitative controlled study focused on a survey tool and student grade data to assess the actual impact of collaborative notes. Did students benefit from using collaborative notes? How did students' self-reports compare to received grades? To mitigate the issue of the self-selection bias there is also a comparison between participating classes and non-participating classes.

- Standardized open-ended interviews were administered to each student participant (Turner, 2010). These interviews involved asking students identical questions during the course of the semester while using collaborative notes. In this way it was possible to see how students themselves assessed collaborative note-taking, and what, if any, benefits or discouragements they encountered. Students were asked a serious of open ended-questions and were not restricted in how to respond.

### Student Performance Findings

Phase one of the experiment looked for evidence that small groups taking notes collaboratively performed better than their peers. There were two primary measures: grades and independent learning outcome performance. Ten classes participated in the experiment that included a total of 247 students where 51 students were in an experimental group (small groups using collaborative notes) and 196 students were in the control group (students in the same class who took notes individually). The benefit of the first control group was that all participants received an identical stimulus. The problem is that, given the voluntary nature of student involvement, there is a potential for selection bias. To account for the issue of selection bias a second control group, a class of an additional 32 students, was used. The control class was taught identically to the experimental sections, but the offer to take notes collaboratively was never extended. By using two control groups it was possible to minimize selection bias.

A final experimental design looked to content knowledge measures outside grades. In one of the experimental classes the college performed a student learning outcomes pre-test and post-test. These tests are designed by a panel of instructors to assess the effectiveness of classes in achieving their learning outcomes. In conjunction with the experimental design, the pre-tests and post-tests helped to detect if either the experimental or control population started at different baseline knowledge levels and to compare – apart from grades – how the groups performed after the stimuli.

Table 1 shows the class breakdowns. Unsurprisingly, each section had slightly larger female populations. The largest population of students came from American government sections. All students were either freshmen or sophomores. Further demographic information was not collected due to privacy concerns.

Table 2 shows that the average grade across all classes and groups (experimental and control) was 72.02%. Students in the experimental group had an average grade of 79.66%, while the control group average was a 71.87% (a difference of 7.79%). Students who participated in collaborative notes performed nearly a single letter grade better than did their peers in the same classes. The ANOVA result found significance at the .01 level ($F = 5.47$, $p < 0.01$). Further, Bartlett's test for equal variance returned a non-significant value, indicating a reliable ANOVA model. It is possible to say there was a statistically significant difference between the control group and the experimental group.

Is this difference due to a selection bias? The control class (a population of 32 as noted earlier) was compared to the experimental group. The average grade for the control class was 70.3%, nearly identical to that of the average control group (71.87%), and there was no significant difference in ANOVA results. As a result, it is possible to say that the grade data is probably not skewed and that the improvement to grades was likely due to the influence of collaborative notes as a variable. See Table 3.

But did the notes result in additional learning? In one experimental class, as already described, a pre-test and post-test, independent of the instructor, was administered by the department. The college in question administers these tests to students during the first week of classes to assess their baseline knowledge of a particular subject. During the last week of the semester students are then given the same test again. The post-test is required to be worth a certain percentage of a student's grade. This allows the school to measure student-learning outcomes. These tests are applied to all instructors and are not created by any one instructor but a panel of faculty in the discipline. One of the experimental classes for collaborative notes was also selected by the department to be administered a pre-/post-test. It was possible to use this data to see how the experimental group compared to the control group on an independent, professor agnostic, metric. Results are shown on Table 4.

Students who were part of the experimental group (35.41%, N = 7) performed worse than their peers (38.54%, N = 43) on the pre-test. On the post-test students who participated in collaborative note-taking did significantly better (72.49%) than their peers (64.17%). Presumably this means that the students who participated in the study had lower levels of baseline knowledge at the outset, but they had a more robust level of knowledge by the end of the class and the experiment than did their peers who had taken notes individually. The difference of 8.28% is strikingly similar to the difference in grades. As the results indicate, these are difficult tests for students. The experimental group did not just perform almost a letter grade better in grades; they also performed almost a letter grade better on the pre/post tests.

In addition to grade and pre-/post-test data, additional questionnaires were distributed to students online at the end of each semester to see what students believed about their performance and technological skill. Students were asked about the propensity to use technology, to self-report on the usefulness of collaborative notes, to consider the likelihood of using collaborative notes in the future, and to identify the areas in which they self-reported improvements using collaborative notes compared to other methods. Unsurprisingly, students who participated were at least moderately interested in technology overall. Students who participated indicated they at least sometimes turned to technology to solve problems. See Figure 1.

In order to assess student outcomes, we asked a series of questions with Likert scale responses. It was important to assess students' perception of usefulness, likelihood of using again, likelihood of use in future classes, and areas of use. The first question asked students for their enjoyment. Did students like using collaborative notes? If students did not find the experience likable, the probability that they would employ them would be low—an important measure if a faculty member wants to implement a practical solution. On this measure students overwhelmingly said yes. Seventy students (71.43%) agreed, or strongly agreed, that they enjoyed collaborative notes. See Figure 2.

Another important question was whether students would want to use this method in another class. Even if under testing conditions students found the notes useful, would they continue to employ the tool without assistance or aid from the professor? Again overwhelmingly students answered yes. Sixty-seven students (81.71%) indicated they were planning on using collaborative notes again in a future class. See Figure 3.

Table 1
*Class Overviews*

| Class | Student Participants | | Number of Sections | Male | Female |
|---|---|---|---|---|---|
| | Total | Test Group | | | |
| American Government | 120 | 29 | 4 | 55 | 65 |
| State and Local Politics | 50 | 7 | 2 | 20 | 30 |
| Comparative Politics | 27 | 4 | 2 | 10 | 17 |
| Introduction to Psychology | 26 | 5 | 1 | 10 | 16 |
| Research Methods (Psychology) | 24 | 6 | 1 | 11 | 13 |
| Total | 247 | 51 | 10 | 106 | 141 |

Table 2
*Class Grades*

| | Total Participants | Average Grade | Std. Dev. | Minimum Grade | Maximum Grade |
|---|---|---|---|---|---|
| All Students | 247 | 72.02% | 16.47 | 35.33% | 99.97% |
| Test Group | 51 | 79.66% | 9.33 | 59.74% | 91.57% |

Table 3
*Control Class*

| | Total Students | Average Grade | Std. Dev. | Minimum Grade | Maximum Grade |
|---|---|---|---|---|---|
| Control Class (American Government) | 32 | 70.30% | 15.32 | 44.46% | 93.50% |

Table 4
*Pre-Post Test Results*

| State and Local Politics | Total Participants | Pre Test Avg. (Control Group) | Post Test Avg. (Control Group) |
|---|---|---|---|
| Control Group | 43 | 38.54% | 64.17% |
| Experimental Group | 7 | 35.41% | 72.49% |

Figure 1
*Employment of Technology*

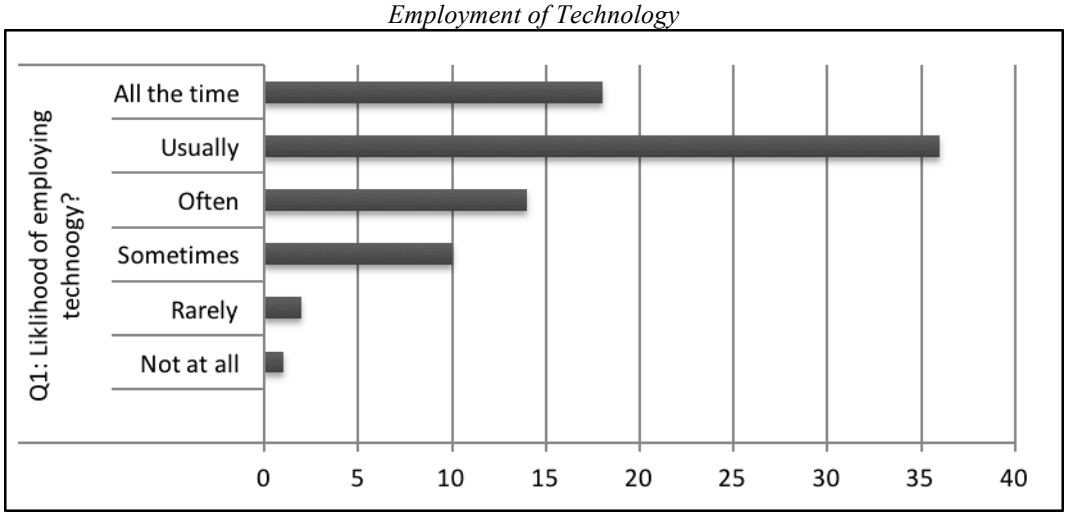


Figure 2
*Collaborative Note Enjoyment*

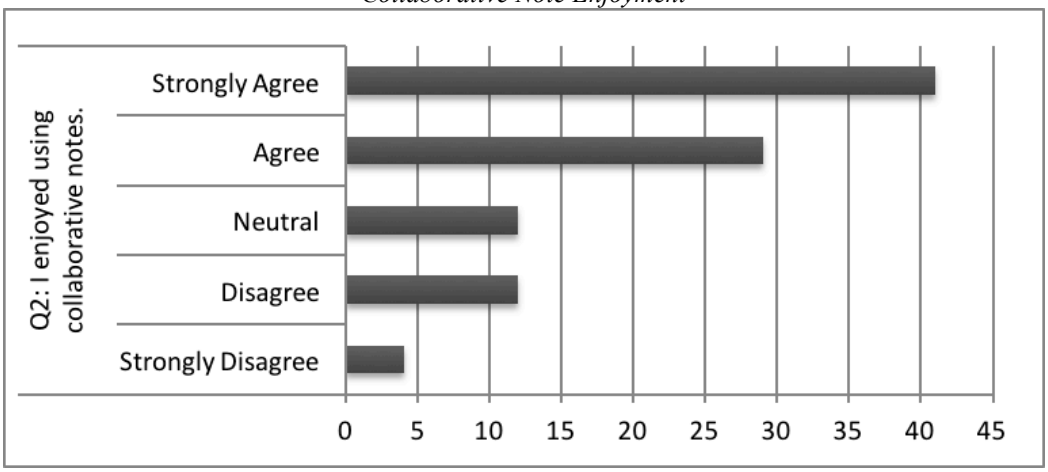
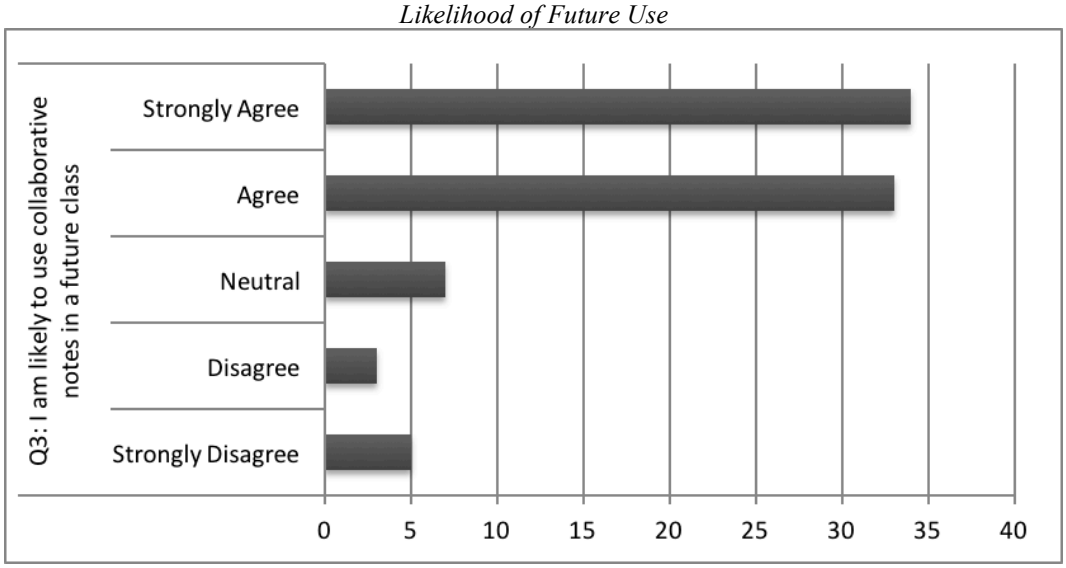



Figure 3
*Likelihood of Future Use*




Would students have used notes again in the current class? Almost universally participants said yes. This is interesting because it means that students increased their likelihood of collaborative notes if a professor or teaching assistant is taking an active role. This is fascinating because students did not rank professor interaction highly in their evaluation of collaborative notes. In this case, seventy-three students (89%) reported they would use collaborative notes again in their current class. See Figure 4.

It was also enlightening to see what students reported as the most useful aspects of collaborative notes. The highest marks went to *preparing for tests*, *learning*, and *interacting with classmates*. In a close fourth came *pay attention*. Clearly, students found similar benefits as to those that were postulated. Although we thought students might feel closer to the professor, this did not appear highly ranked by students. See Figure 5.

**Student Interview Findings**

In phase two of the experiment, a standardized open-ended interview design was employed. At the end of each semester students submitted their responses to a number of questions concerning their feelings and thoughts on the small groups and the collaborative notes. Questions were structured to elicit honest and student-worded responses from the participants in the experimental population. Across all classes, 51

Figure 4
*Would Students Use Collaborative Notes Again?*

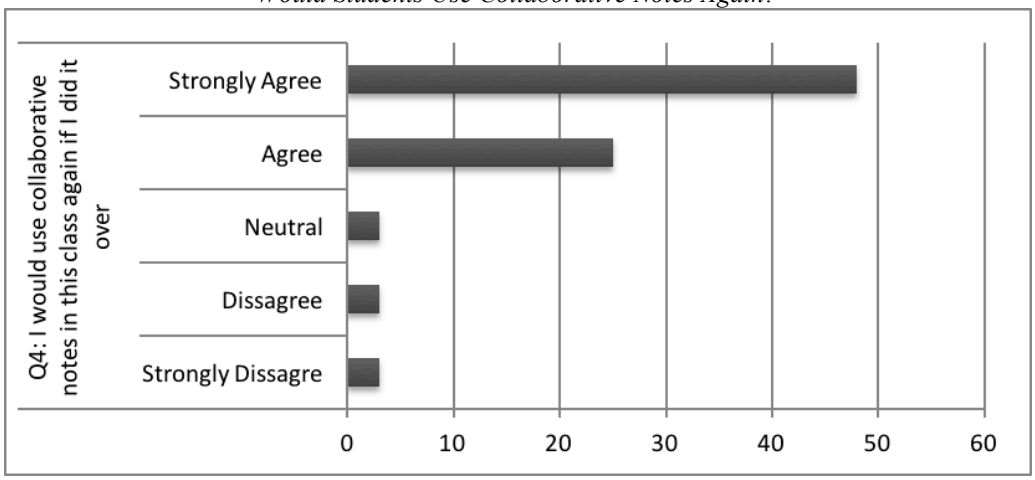
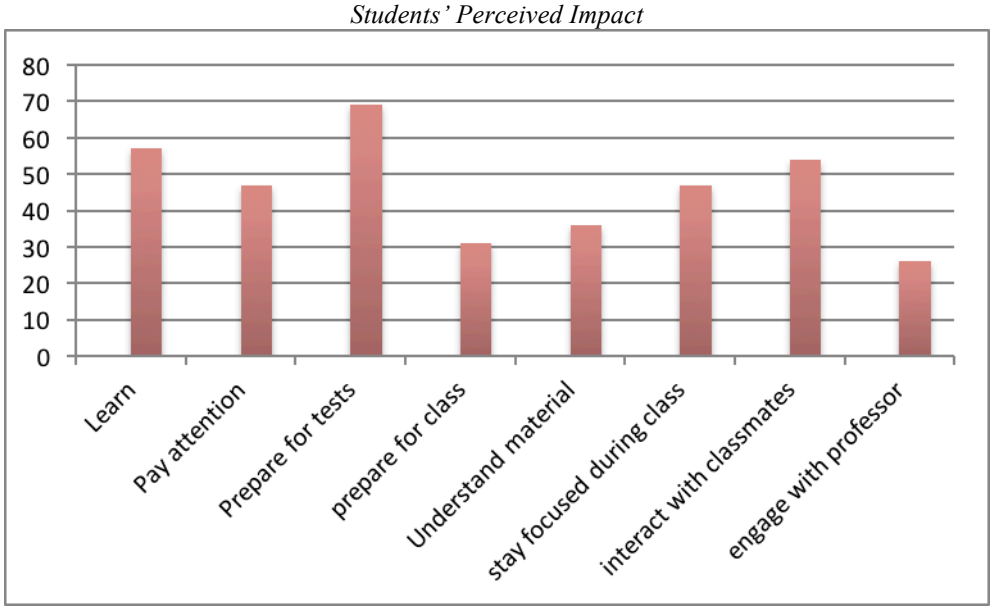



Figure 5
*Students' Perceived Impact*




participating students were interviewed (the entire experiment group population). Of those, 38 students provided responses. The interviews were conducted online at the conclusion of each semester. Classes were asked the listed questions in random order to avoid ordering bias.

There seemed to be general agreement that there were positive benefits to using collaborative notes (See Table 5). This seemed consistent with the fact that no students dropped from the program in any class. But student answers coalesced around three areas: organization, group learning, and improved studying. Students nearly universally liked the ability to create structure.

Shared responsibility meant that students could specialize in their note-taking. Especially fascinating and unanticipated in the research was that the division of labor allowed students to learn from each other. Students found watching the note-taking habits of their group not only useful for content learning, but also for perfecting the skill of note-taking in other classes. Students generally expressed they were able to take better individual notes in non-experiment classes by learning a wider range of note-taking techniques.

Table 5
*What, if any, are the positive benefits of using collaborative notes?*

| | Student Responses |
|---|---|
| Keywords | Organization, Structure, and Studying |
| Key Concepts | Division of Labor |
| | "If one person is typing and another is listening, they can add on to the notes to better understand. Most teachers talk while things are [visually] presented, this way you can have a listener, typer, and catcheruper." |
| | "It's very helpful when studying for the test. It's hard to miss anything when three people are taking notes on something instead of just one." |
| | Shared Responsibility |
| | Easy to "add and delete highlighting" and "making changes after or during class easily." This allowed students to have "a chance to hear what [the professor] says." |
| | Communication |
| | "Can talk on it outside or inside of class" |
| | "Interacting with classmates." |
| | Learning How to Take Notes |
| | "You can see how others take notes." |
| | "We each bring good habits, so we can learn from each other" |
| | "You get different takes on, on how people take notes. Great to see different strategies, highlighting, etc. different ways of taking notes. [You] can apply the styles of note-taking [of] others." |

Given the lack of note-taking preparation in most institutions, this was a useful finding.

Table 6 reports data about problems or issues students faced. The most reported issue was the fact that the first few classes could seem unorganized. Many students reported the coordinating with others was a new skill set. Students had to adjust to a very real mental hurdle—notes are supposed to be individualized. Working together required communication with others, and this is something that took time. Students reported it took one or two days to get together. It would appear then, that until students learned to work as a team, the organizational benefits were not present. This would indicate early help from the professor might be necessary to assist students in accepting the idea of collaborative notes.

Some students also struggled with using technology. They did not like typing and actually preferred a pen and paper. When asked follow-up questions on why this was the case, these students simply reverted to noting they were *non-tech students* and never offered any indication of why that was their preference. Many of the students in the samples came from primarily two-year institutions. Another limiting factor was access to a laptop or tablet. These students would likely want to participate, but were be barred from doing so for technological reasons. One of the advantages of Google Drive is the fact it is free. Unfortunately, student access to a computing device is a shortcoming that is not currently possible to overcome at many institutions.

Students universally perceived themselves as earning better grades than they were expecting (See Table 7). This issue is analyzed statistically and reported in detail later, but here the main interest was in students' perceptions of their grade. Students self-

Table 6
*What problems or issues have you encountered with using the collaborative notes?*

| | Student Responses |
|---|---|
| Keywords | Coordination, Organization, Size, and Technology |
| Key Concepts | Collaboration vs. Individualists<br>"In the beginning it was confusing because nobody knew what they were doing [and] everyone all at once would try to do the same thing until with time everyone knew what they were doing and eventually got organized."<br><br>"Hard in the beginning to get on the same page. Took one or two days to get together."<br><br>Early in the semester it "can be unstructured if you don't get together."<br><br>Groups need to be teams<br>Groups should "sit down and decide who should do what task beforehand" instead of leaving it to the process of trial and error.<br><br>Group Size<br>"Need to be in smaller groups (of three or four); need assigned positions"<br><br>"Like three people is good."<br><br>Groups should be student determined<br>"Don't force us [about] how to do it"<br><br>Desire to use pen and paper<br>"Prefer paper"<br><br>"Non-tech students" |

Table 7
*Do you believe, or notice, that collaborative notes improved your grades in this class?*

| | Student Responses |
|---|---|
| Keywords | Achievement, Passing, and Performance |
| Key Concepts | "It has helped me achieve the grades I want."<br>"[Collaborative notes] helped me to pass." |

reported they were doing better, or performing better, than they had intended or expected.

Of particular interest was the likelihood that students would use collaborative notes again in future classes (See Table 8). Some students indicated they would be taking classes together in the future to maintain their newly found group. But nearly all participants noted in some form that they would do it again. To assess this, students who took classes together again in order to use collaborative notes were interviewed in subsequent semesters—an issue handled in the next section.

**Issues Raised by Students**

Students were also asked to raise their own issues and questions, as well as to provide information for those thinking about collaborative notes. Technologically, students seemed to prefer laptops or iPads. Interestingly, although not related to the

Table 8
*Would you use collaborative notes again in another class?*

| | Student Responses |
|---|---|
| Keywords | Yes |
| Key Concepts | "I would do [collaborative] notes again"<br>"I would take notes with others again . . . and I grew up in the paper and pencil era!" |

research here, students preferred laptops or iPads to Android tablets.

Another problem not foreseen was the difficulty of graphing on laptops. Tablets could draw, but for those using traditional laptops, a student noted, "Graphs can be difficult to incorporate." While it is possible to create graphs in Google Drive, this was apparently not intuitive enough. A review of students' notes revealed that no one had opted to do so. Several groups, however, did take a photograph of a graph drawn by hand and inserted that picture into the notes file.

There were also a variety of positive issues raised. Many students liked that electronic notes were "eco-friendly" and saved the need for paper. Others wanted to express that it was not necessary to be a computer hacker to take collaborative notes. "Don't worry about needing to be too tech savvy," said a student. For those who were technically inclined, a participant noted, "Think it's cool that professors allow the use of laptops in the classroom." For those professors who used PowerPoint, students liked the ability to mesh those file types with their electronic notes, as a student wrote, "Can put PowerPoint and notes together."

## Conclusion and Future Research

It is clear from prior research that one of the focal points for pedagogical inquiry should be note-taking (Ambruster, 2000; Kiewra, 1985; Makany, Kemp, & Dror, 2009). What the research has lacked is a clear direction and pragmatic strategy professors can actually use in their classes. First is an overview of the studying findings and implications, then a review of software, discussion on the limitations of the study and lastly a few concluding comments.

### Study Findings

The results here highlight a number of important insights. First, student performance can be affected by note-taking strategies. This finding is in agreement with the prior literature (Titsworth & Kiewra, 1998). These gains manifest themselves both in grades and conceptual retention. Second, students, it appears from the data, can learn from both working with others in note taking and watching others take notes. The isolation of traditional notes is probably most acute in at risk populations. Faculty rarely guide students, at-risk or otherwise, in the art of note-taking. Unless fellow students simply take the initiative to help, poor note takers have no opportunity to improve. Collaborative notes offer students the opportunity to improve a rarely modeled skill.

Third, students who take notes together can spend more cognitive energy on class material. This particular insight should help faculty who worry about the rows of computers they face in today's classroom and the potential shortcoming traditional, individualized, notes have in that environment. As Mueller and Oppenheimer (2014) have demonstrated, students who take notes individually on computers do worse at learning material than their longhand counterparts. The data here indicates that these effects might disappear if students take notes together in small groups. Given that the laptop is not likely to be toppled by the pen, it would be fruitful if future research compared student cognitive performance on laptops in small groups. The assumption in the Mueller and Oppenheimer study was that students would be taking notes in isolation. Under such conditions they apparently become stenographers and not deep thinkers. But as the qualitative research shows here, collaborative notes force students to do one job only and one job well during note-taking. In this environment, no one student is wasting cognitive energy writing everything down. Instead, they are simply playing their individual role, leaving the rest of their time to think more deeply on the material presented.

### Software, Realism, and Education

Another insight is that software selection for higher education needs a healthy dose of realism. Most prior experiments concerning technology have used expensive and obscure software (Kittle & Hicks, 2009). Further studies are rarely conducted, and the average college cannot afford the potential solution even if more data could be collected. Any collegiate institution, in contrast, can implement free consumer-based software such as Google Drive (or QUIP or iWork). Far too

much experimentation in previous research has focused on tools that the average classroom cannot access. Software needs to be targeted at widespread adoption if it is to be considered a realistic tool. Future research would do well to expand on the size of the experiment performed here. Such an experiment, by design, is easily performed at a wide range of schools given the low entry cost.

Classrooms of all types—from lecture based to flipped—assume that students are, and are capable of, taking effective notes. Yet very little time is spent pedagogically attempting to improve this aspect of student learning. The data here indicates that investing more time in note-taking strategies could continue to improve student success, which is an area of deep concern in higher education today and will likely remain so for the foreseeable future. Imagine the possibilities if student success could be shifted—even slightly—by a low cost intervention such as collaborative note-taking. Small groups and Google Drive can be implemented and tested anywhere.

**Limitations**

There are also several limitations of the current research. As is often the case with pedagogical studies, the total population of the study is relatively low. Further, despite the attempts to control for the issue of selection bias, the lower sample size increases the probability of extreme results. Future research, however, by starting from the basic model presented here, could expand the work to a larger population to see if the effects found continue to measure significantly. The findings are also limited in their scope: social science classes. While it is reasonable to assume the effects would manifest themselves across the curriculum, the limited nature of the study cannot demonstrate that possibility with certainty. But there are two big reasons to be optimistic in the face of these limitations. First, by having classes across a number of content areas it is possible to control for professorial variation. Many pedagogical studies are often limited to a single case study. Here, while the total population is limited, it does extend across a number of classes, fields, and professors. Second, the pre- and post-test data helps demonstrate that the sample population did not start off with higher baseline knowledge. To the contrary, the experimental population apparently had lower knowledge levels. Future research could expand on the pre- and post-test measures to see how deep or widespread this collaborative learning penetrates. Given this, the results of such a significant difference are encouraging for future research.

**Conclusion**

The early evidence indicates that collaborative student note-taking in small groups has improved student performance both as measured by grades and by external student learning outcomes. Collaborative note-taking appears to improve note-taking skills which are crucial in academia. The data suggests there is a potentially simple and pragmatic way for faculty to improve student learning and implement laptops and mobile devices in their classrooms. Small groups learning and taking notes together appear to be a potent academic tool.

Students will continue to use computers and mobile devices, and they will increasingly use these devices in class. The rise in use is inevitable as more digital natives, and post-digital natives, enter higher education. How will faculty manage this shift? One possibility, and the easiest, is to simply continue the classical formula: lecture and individualized notes. The data here suggestions that professors should not be passive agents as mobile technologies enter into the classroom. Instead, they should harness this new technology to improve student note-taking and in the process improve student success.

Students will be most successful if we recognize the importance of small groups. Students need a space to learn how to take notes. Small groups create a space where students can not only better learn the current content, but also improve on the skill of note-taking itself. Mobile technology is allowing students to interact in a way never before possible. Faculty will need to assist if we want these devices used in positive ways that will enhance and not detract from learning. In short, it might be worth considering using small groups for taking notes together online in your next class.

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